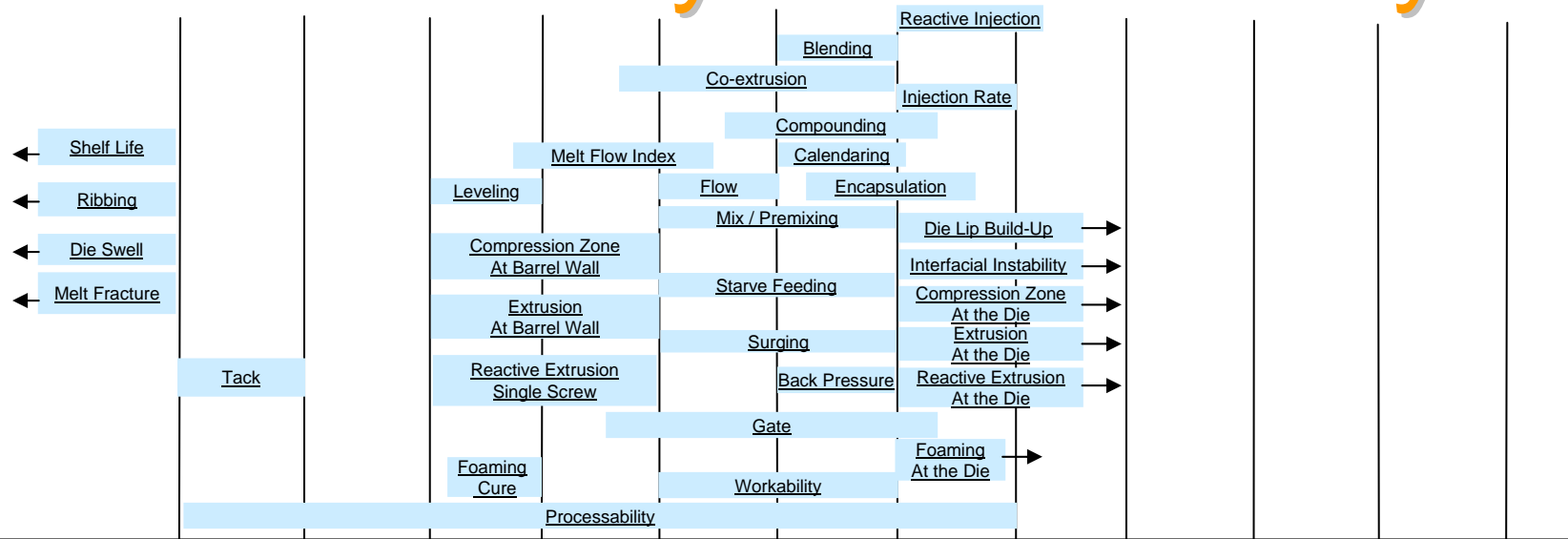
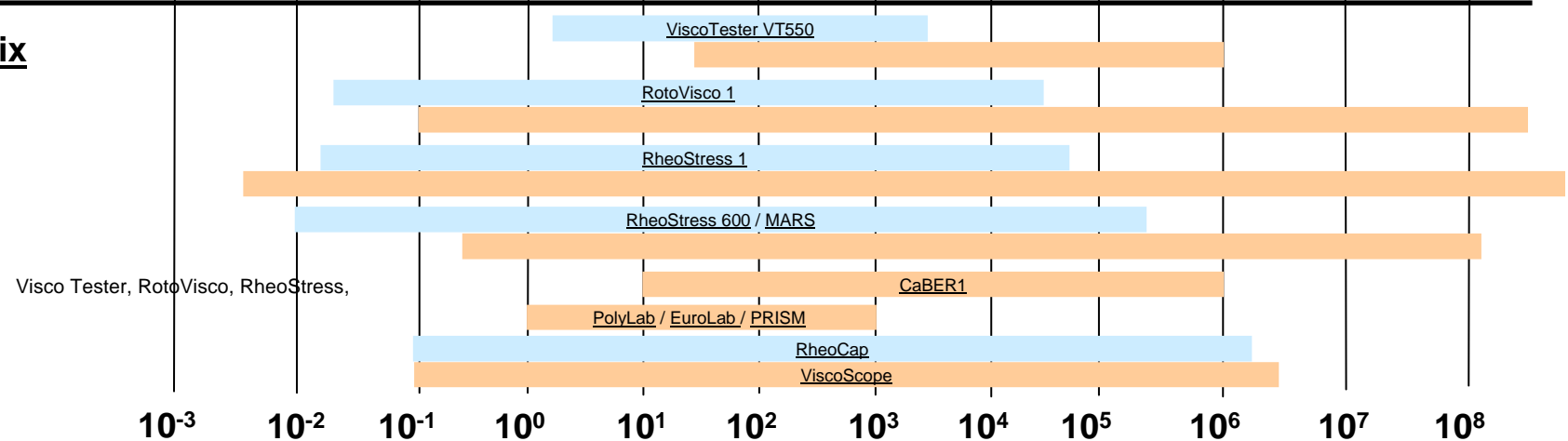


Interactive Polymer Dictionary

Common Terms



Equipment Matrix



Visco Tester, RotoVisco, RheoStress,



Rheology Solutions

Measurement Range (Shear Rate s⁻¹)
 Measurement Range (Viscosity mPa.s)

- EuroLab and PRISM are brand names of the Thermo Electron Corporation
- MARS, CaBER and PolyLab are HAAKE brand names of Thermo Electron Corporation Karlsruhe Germany GmbH
- ViscoScope torsional motion viscometers is brand name of Marimex Industries Corporation

Industry Term: Back Pressure

- Process:* Production (Extrusion).
- Definition:* The resistance which reduces forward flow in an extruder.
- Measurement Information:* Measurement of shear viscosity, and viscous modulus (G'), measured on a Controlled Stress (CS) Rheometer using a flow curve (displays viscosity) and a frequency sweep (displays G').
- Rheology Solutions Instrument:* HAAKE RheoStress, HAAKE MARS.



Industry Term: Blending

<i>Process:</i>	Production.
<i>Definition:</i>	Combination of two polymers which are not bonded to each other to give the desired physical or chemical properties.
<i>Measurement Information:</i>	The effects of changing blend technique or proportions are seen in the process during the physical mixing process and afterwards during extrusion. A mini blender and extruder are best suited to monitor these differences. The effects on the final melt can be measured using rheometry (CS Rheometer) through changes in viscoelastic properties using a frequency sweep, and shear properties, using a flow loop and measuring the yield point if it exists. On-line changes in the shear viscosity can also be monitored using on-line or in-line techniques.
<i>Rheology Solutions Instrument:</i>	PRISM TSE, HAAKE PolyLab & RheoMex, HAAKE PolyDrive .



Industry Term: Calendering

<i>Process:</i>	Production.
<i>Definition:</i>	Formation of thermoplastic sheets between counter-rotating rolls.
<i>Measurement Information:</i>	The processability and quality of the sheets depend on viscoelastic properties, measured on a CS rheometer with a frequency sweep and on shear properties, which can also be measured with a CR (Controlled Rate) viscometer.
<i>Rheology Solutions Instrument:</i>	HAAKE ViscoTester, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.



Industry Term: Co-extrusion

<i>Process:</i>	Production (Extrusion).
<i>Definition:</i>	The process of extruding more than one substance at a time to form a multi-layer compound.
<i>Measurement Information:</i>	Relative processability of one co-extruded compound to another is best judged on a mini-extruder.
<i>Rheology Solutions Instrument:</i>	PRISM TSE, HAAKE PolyLab & RheoMex.



Industry Term: Compounding

<i>Process:</i>	Production (Compounding).
<i>Definition:</i>	Combining polymers and other materials by dry blending or melt state blending.
<i>Measurement Information:</i>	Changes in the properties of a compounded material are best assessed using absolute measurements from a flow curve and a frequency sweep on a CS rheometer. Relative processability can be measured on miniature dry blenders and melt compounders.
<i>Rheology Solutions Instrument:</i>	HAAKE RheoStress, HAAKE MARS, PRISM TSE, HAAKE MiniLab, CAHN TGA.



Industry Term: Compression Zone

<i>Process:</i>	Production (Extrusion).
<i>Definition:</i>	The second zone in an extruder screw. It receives material from the feed zone and delivers it to the metering zone.
<i>Measurement Information:</i>	Changes in the compression zone temperatures and dimensions directly influence the processability of the product and can be measured using mini-extruders with variable screw geometric configuration.
<i>Rheology Solutions Instrument:</i>	PRISM TSE, HAAKE PolyLab & RheoMex, HAAKE PolyDrive.



Industry Term: Die Lip Build Up (Die Drool)

<i>Process:</i>	Production (Extrusion).
<i>Definition:</i>	A gradual (intermittent) formation of initially liquid deposit at the die exit. This solidifies and grows.
<i>Measurement Information:</i>	Factors influencing die drool are uncertain, it has been suggested that molecular weight, molecular weight distribution, and viscoelastic properties play a part. These can be monitored on a CS rheometer using a frequency sweep. Changing process parameters on a mini-extruder can often give reliable indications of the onset of die-drool.
<i>Rheology Solutions Instrument:</i>	HAAKE RheoStress, HAAKE MARS, HAAKE PolyLab & RheoMex, HAAKE PolyDrive, PRISM TSE.



Industry Term: Die Swell (Extrudate Swell)

- Process:* Production (Extrusion).
- Definition:* Die swell occurs when an extrudate has larger diameter than the die. Caused by the release of stresses in the extrudate leaving a contraction – the extrudate ‘remembers’ it’s original shape and attempts to return to it.
- Measurement Information:* Die swell is influenced by normal stresses in the system, and by the viscoelastic properties of the melt. It is possible to measure these using a CS rheometer (first normal stress difference and frequency sweep measurements). In addition, die swell is related to the length of the die, a die swell test can be used to directly measure die swell on production- or small-scale extruders.
- Rheology Solutions Instrument:* HAAKE RheoStress, HAAKE PolyLab & RheoMex, HAAKE PolyLab & Die Swell Tester, HAAKE PolyDrive.



Industry Term: Encapsulation

- Process:* Production (Extrusion).
- Definition:* Caused by layer non-uniformity in areas of high shear (eg the wall of the die). This causes lower viscosity materials to migrate to the die wall.
- Measurement Information:* Encapsulation is governed by the shear viscosities of the materials, and on their viscoelastic properties, which can be measured on by a frequency sweep and a flow curve respectively on a CS rheometer. A relative measurement of encapsulation may be made by monitoring extrudate swell on either full- or small-scale extruders.
- Rheology Solutions Instrument:* HAAKE RheoStress, HAAKE MARS, HAAKE PolyLab & RheoMex, HAAKE PolyLab & Die Swell Tester, HAAKE PolyDrive.



Industry Term: Extrusion

Process:

Production.

Definition:

Extrusion is the technique employed to encourage heat and mass transfer, in turn encouraging phase changes in (usually) polymeric materials, continuously changing their shape.

Measurement Information:

The efficient extrusion of a material usually depends on it's molecular weight, molecular weight distribution, viscoelastic properties (these can be measured using a frequency sweep), and on the behaviour in shear including the yield point if it exists (which can be measured using a CR viscometer or CS rheometer using a flow curve and yield point measurements). Relative changes in the process can be predicted using a mini-extruder.

Rheology Solutions Instrument:

HAAKE PolyLab & RheoMex, & HAAKE ProFlow, HAAKE PolyDrive, PRISMTSE, Marimex ViscoScope, HAAKE RheoStress, HAAKE MARS, HAAKE RheoCap.



Industry Term: Flow

- Process:* Pumping/ Cure.
- Definition:* Measure of the ability of a wet film to be moved (by gravity or other force).
- Measurement Information:* The rate of flow of a liquid is governed by its properties in shear, including the yield point, measured with a CR viscometer, and by the viscoelastic properties of the liquid, as measured by a CS rheometer. CR measurements can often be made in-line.
- Rheology Solutions Instrument:* HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS, Marimex ViscoScope.



Industry Term: Foaming

<i>Process:</i>	Production.
<i>Definition:</i>	Continuous formation of bubbles having high surface tension which remain beyond the disengaging surface. This is due to the introduction of gas in the material.
<i>Measurement Information:</i>	The longevity of the foam is related to extensional properties, measured with an extensional rheometer, on the viscoelastic properties of the liquid, measured using a frequency sweep on a CS rheometer and on the properties in shear, measured using a flow loop on a CR or CS instrument.
<i>Rheology Solutions Instrument:</i>	HAAKE CaBER, HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.



Industry Term: Gate

- Process:* Production (Extrusion).
- Definition:* The channel through which the molten resin flows into the cavity.
- Measurement Information:* Flow through the gate depends on extensional properties, measured on an extensional rheometer, and on viscoelastic properties of the melt, measured by a frequency sweep on a CS rheometer. Finally, the properties of the melt in shear flow are important, these can be measured with a CR viscometer using a flow curve.
- Rheology Solutions Instrument:* HAAKE CaBER, HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.



Industry Term: Injection Rate

- Process:* Production (Reaction Injection).
- Definition:* The flow rate of melt coming out of the nozzle. Melt comes out in the form of a jet and spreads inside the mould in the shape of the space between the core and cavity.
- Measurement Information:* The shape of the jet is dominated by extensional properties, by behaviour in shear (measured with a flow curve on a CR viscometer), and by viscoelastic properties (measured by a frequency sweep on a CS rheometer). The coverage inside the mould is dominated by the latter two.
- Rheology Solutions Instrument:* HAAKE CaBER, HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.



Industry Term: Interfacial Instability

- Process:* Production (Co-extrusion).
- Definition:* An internal defect, seen in co-extrusion when wavy lines appear at the polymer/ polymer interface.
- Measurement Information:* The exact nature of this instability is not fully understood, properties in shear, measured using a CR viscometer are thought to dominate. Viscoelastic properties (frequency sweeps using CS rheometer) have also been shown to be a possibility for prediction of the defect, especially in cases where high stresses are present.
- Rheology Solutions Instrument:* HAAKE RheoStress, HAAKE MARS.



Industry Term: Levelling

<i>Process:</i>	Cure.
<i>Definition:</i>	The degree of flow for a wet film can after application to remove irregular marks.
<i>Measurement Information:</i>	Flow properties at low shear dominate the possibilities for levelling, these properties are measured using yield point and flow loop data, on a CR viscometer. Viscoelastic properties also play a part in levelling, they are measured using a frequency sweep on a CS rheometer.
<i>Rheology Solutions Instrument:</i>	HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS.



Industry Term: Melt Flow Index (MFI)

<i>Process:</i>	QA/QC.
<i>Definition:</i>	Grams per 10 min pushed from a die of prescribed dimensions (ASTM standard) with a specified load and temperature.
<i>Measurement Information:</i>	MFI is usually measured by a dedicated MFI measuring device as a QC control to release product. The MFI of a melt depends on the properties of the melt in shear flow, measured with a capillary or CR viscometer and sometimes, on the viscoelasticity of the melt, measured on a CS rheometer using a frequency sweep.
<i>Rheology Solutions Instrument:</i>	HAAKE RheoStress, HAAKE MARS, HAAKE RheoCap, HAAKE MFI.



Industry Term: Melt Fracture

<i>Process:</i>	Production (Extrusion).
<i>Definition:</i>	Flow instability. When a polymer is highly elastic, extrudate shows poor surface quality at high extrusion rates. Due to extruder set-up and elastic limits of polymer causing turbulent flow conditions. The upper limit for die swell testing.
<i>Measurement Information:</i>	Viscoelastic properties are important measures of the propensity of a melt to exhibit melt fracture. They are measured using a frequency sweeps on a CS rheometer. The onset of melt fracture can be examined on a small scale using a mini-extruder, die swell can be monitored using die swell measurements.
<i>Rheology Solutions Instrument:</i>	HAAKE RheoStress, HAAKE PolyLab & RheoMex, HAAKE PolyLab & Die Swell Tester, HAAKE PolyDrive.



Industry Term: Mix / Premix

- Process:* Production, raw materials.
- Definition:* A moulding compound of a thermosetting resin prepared prior to and apart from the moulding operations and containing all components required for moulding.
- Measurement Information:* The efficiency of the premix is dependent on the surface properties of the particles, their bulk density, particle size etc. Relative measurements of the costs for mixing various combinations can be estimated using the torque and rpm relationship in instrumented mixers.
- Rheology Solutions Instrument:* PRISM Pilot Mixer.



Industry Term: Processability

<i>Process:</i>	Production.
<i>Definition:</i>	Related to the amount of energy required to perform the relevant production steps on a material.
<i>Measurement Information:</i>	Depending on the process, small scale machines (extruders, mixers etc) can be used to estimate (through their relative torque, temperature and rpm inputs) the relative processability of different materials. Direct measurement of extensional properties, using an extensional rheometer, of viscoelastic properties, eg frequency or temperature sweeps, using a CS rheometer and of the behaviour in shear – using flow curves from a CR viscometer - can all provide valuable information for predicting the processability of a given material.
<i>Rheology Solutions Instrument:</i>	HAAKE CaBER, HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS, HAAKE PolyLab RheoMex & RheoMix, HAAKE PolyDrive, Marimex ViscoScope.



Industry Term: Reactive Extrusion

- Process:* Processing (Extrusion).
- Definition:* Extrusion in which the components chemically combine to form a new product with predefined properties.
- Measurement Information:* Reactive extrusion efficiency relies on optimum molecular weight, molecular weight distribution. These properties can be related through the viscoelastic properties of the liquid, which can be measured using a frequency sweep on a CS rheometer. In addition, shear flow governs the flow of the melt through the extruder, flow curve measurements on a CR viscometer or capillary viscometer are important. In-line measurements of shear properties are also possible. Relative information can be obtained using mini-extruders.
- Rheology Solutions Instrument:* HAAKE PolyLab & RheoMex, & HAAKE ProFlow, HAAKE PolyDrive, PRISMTSE, Marimex ViscoScope, HAAKE RheoStress, HAAKE MARS, HAAKE RheoCap.



Industry Term: Reaction Injection Moulding

- Process:* Production (Extrusion).
- Definition:* Integrated mixing (rapid impingement mixing) and injection of two chemically reactive liquid streams, into a mould, resulting in simultaneous polymerization, cross-linking and formation of the part.
- Measurement Information:* Reactive injection efficiency relies on optimum molecular weight, molecular weight distribution. These properties can be related through the viscoelastic properties of the liquid, which can be measured using a frequency sweep on a CS rheometer. In addition, shear flow governs the flow of the melt through the extruder and mould, flow curve measurements on a CR viscometer or capillary viscometer are important. In-line measurements of shear properties are also possible. Relative information can be obtained using mini-extruders.
- Rheology Solutions Instrument:* HAAKE PolyLab & RheoMex, & HAAKE ProFlow, HAAKE PolyDrive, PRISMTSE, Marimex ViscoScope, HAAKE RheoStress, HAAKE MARS, HAAKE RheoCap.



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Industry Term: Ribbing

- Process:* Roller Coating Application, Cure.
- Definition:* A striped film in the direction of roll coating.
- Measurement Information:* Flow properties at low shear dominate the possibilities for levelling, these properties are measured using yield point and flow loop data, on a CR viscometer. Viscoelastic properties also play a part in levelling and in the advent of ribbing, they are measured using a frequency sweep on a CS rheometer.
- Rheology Solutions Instrument:* HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress.



Industry Term: Shelf Life

<i>Process:</i>	Storage.
<i>Definition:</i>	The maximum time interval in which a material may be kept in a usable condition during storage.
<i>Measurement Information:</i>	Shelf life depends, amongst other things on how the product behaves rheologically. Yield point and shear viscosity – measured at low shear rates on a CR viscometer – dictate phase separation. Frequency sweeps, performed on a CS rheometer indicate the continuing strength of the internal structure.
<i>Rheology Solutions Instrument:</i>	HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress.



Industry Term: Starve Feeding

<i>Process:</i>	Production (Extrusion).
<i>Definition:</i>	Feeding the extruder at a rate below the capacity of the machine.
<i>Measurement Information:</i>	In this case output becomes a function of the feeder, not the extruder.
<i>Rheology Solutions Instrument:</i>	PRISM TSE, HAAKE PolyLab & RheoMex, HAAKE PolyDrive.



Industry Term: Surging

<i>Process:</i>	Production (Extrusion).
<i>Definition:</i>	Pressure and flow rate instability in the extruder, causing dimensional variations in the product.
<i>Measurement Information:</i>	Flow of a melt is governed by the properties of the liquid under shearing conditions, these may be measured using a flow curve on a CR viscometer. Similarly stored stresses, which can be predicted from the viscoelasticity of the melt on a CS rheometer influence the dimensional stability of the product. Relative measurements of flow rate and temperature in a mini-extruder can aid in the prediction of the onset of surging.
<i>Rheology Solutions Instrument:</i>	HAAKE RheoStress, HAAKE MARS, HAAKE RheoCap, PRISM TSE, HAAKE PolyLab & RheoMex, HAAKE PolyDrive.



Industry Term: Tack

- Process:* Roller Coating (Ink) application.
- Definition:* The property of cohesion between particles (stickiness), the separation force needed for transfer of the material from the roller to the substrate.
- Measurement Information:* The transfer of fluid from one surface to another in this manner is governed by the extensional properties of the fluid, as measured by an extensional rheometer, and by viscoelasticity, which can be measured on a CS rheometer
- Rheology Solutions Instrument:* HAAKE CaBER 1, HAAKE RheoStress, HAAKE MARS.



Industry Term: Workability

<i>Process:</i>	Process.
<i>Definition:</i>	The ease at which mixers blend the components that form the coating material.
<i>Measurement Information:</i>	Flow properties in shear dominate the workability parameter, they can be measured using yield point measurement and flow curves, on a CR viscometer. Viscoelastic properties influence the power required for good mixing, measured using frequency sweeps on a CS rheometer. Instrumented mixers and extruders can measure relative performances for different configurations and blends.
<i>Rheology Solutions Instrument:</i>	HAAKE ViscoTester 550, HAAKE RotoVisco, HAAKE RheoStress, HAAKE MARS, PRISM TSE.



Shear Rate Table

Industry Term	Shear Rate	Industry Term	Shear Rate
Back Pressure	102-103 s-1	Blending	102-103 s-1
Calendaring	102 -103 s-1	Co-Extrusion	<101-103 s-1
Compounding	<102->103 s-1	Compression Zone	<101 s-1 at Barrel Wall >103 s-1 at the Die
Die Lip Build Up	>103 s-1	Die Swell	<10-3 s-1
Encapsulation	103 s-1	Extrusion	<101 s-1 at Barrel Wall >103 s-1 at the Die
Flow	101-102 s-1	Foaming	<1 s-1
Cure	>103 s-1 at the Die	Gate	<101->103 s-1
Glass Transition	10-1-101 s-1	Injection Rate	103 - 104 s-1
Interfacial Stability	>103 s-1	Levelling	10-1-101 s-1
Melt Flow Index	9x10-1-5x101 s-1	Melt Fracture	<10-3 s-1
Mix	101 - 103 s-1	Pre-Mix	102 - 103 s-1
Processability	<10-1-104 s-1	Reactive Extrusion	<101 s-1
Single Screw	>103 s-1 at the Die	Reaction Injection	103 - 104 s-1
Ribbing	<10-3 s-1	Sharkskin	>102 Pa
Shelf Life	<10-4 s-1	Starve Feeding	101-103 s-1
Surging	101-103 s-1	Tack	<10-3 s-1

Equipment Type

Equipment Name	Type
ViscoTester VT550	Rotational Viscometer
RheoCap	Capillary Rheometer
RotoVisco 1	Rotational Viscometer
ViscoScope	On-line Torsional Motion Rheometer
RheoStress	Controlled Stress Rheometers
CaBER 1	Extensional Rheometer
PolyLab/EuroLab/PRISM	Mixers, Extruders
EzTest	Texture Analyser (Universal Uniaxial testing Machine)
MARS	Modular R&D Control Stress Rheometer

Note: The HAAKE PolyLab and PRISM EuroLab are laboratory / pilot scale mixers and extruders and therefore exhibit the same range of shear rates which occur in full-scale processing. Therefore a shear range is not a relevant quantity for this equipment.

The HAAKE CaBER is an extensional rheometer and does not exert shear rates or stresses, but rather extensional ones. The shear rate range of rotational instruments (HAAKE ViscoTester, RotoVisco, RheoStress, MARS) can be expanded using alternative sensor geometries.

The Marimex ViscoScope measures a point value of viscosity at a shear rate determined by the flow profile around it. This is determined by the process itself rather than the measuring equipment.