SV series

Sine-wave Vibro Viscometer

Users' Handbook

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International Div., A&D Company, Limited

Viscometry Revolution!

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■Basis

A. Measurement

1. Viscosity

1. Introduction

Measuring viscosity is an effective method of determining the state (properties of matter) or the fluidity of a liquid or a gas. For example, the viscosity of a liquid is an important parameter for designing the piping in a plant, or transporting crude oil or chemical agent through a pipeline. Viscosity measurement has played an important role in, to say nothing of the petrochemistry industry, a wide range of industries such as the food, printing (ink), medical drug, or cosmetics industries, as well as in quality control during a production process or in various research and development stages for the improvements of quality and performance. Recently, in the electronic engineering industry it has been recognized that controlling viscosity of photoresist fluid, which is used in the production processes of the print circuit board, the cathode-ray tube and the flat liquid crystal display, is a crucial factor in determining the qualities, performances and yields of finished products. Among those industries, it has also been recognized that controlling optimum viscosity reduces production costs.
Furthermore, in the biology and medical fields, viscidity of blood for instance affects hemodynamics and microcirculation, and viscosity is also an important parameter for research of colloidal solutions such as biopolymer solution.

Generally speaking, viscosity is associated only with liquid. Because gas is a relatively inviscid fluid, it is considered that no major errors will be produced if ignoring a force towards the direction of the gas flow that exerts on a plane against the gas (tangential stress†), unless it is not involving a fast-moving object such as a rocket or aircraft. This kind of ideal fluid in which no tangential stress generates when it is in motion (fluid state) is called a **perfect fluid** or an **inviscid fluid**.
Almost all liquid are **viscous fluid** having viscidity. For example, when rotating a drum container filled with water on its vertical central axis, the water that was at rest in the beginning starts moving as being dragged by the container's inside wall and then whirls completely together with the container as if it were a single rigid body. This is caused by the force (tangential stress) having generated in the direction of the flow (movement) on the surface of water and the container's inside wall. A fluid that generates this kind of force is regarded as having **viscosity**. Viscous fluid is further divided broadly into two categories; **Newtonian fluid** that is subject to Newton's law of viscosity, and **non-Newtonian fluid** that is not subject to Newton's law of viscosity.

As described above, fluid can be broadly categorized as shown in Figure 1 below:

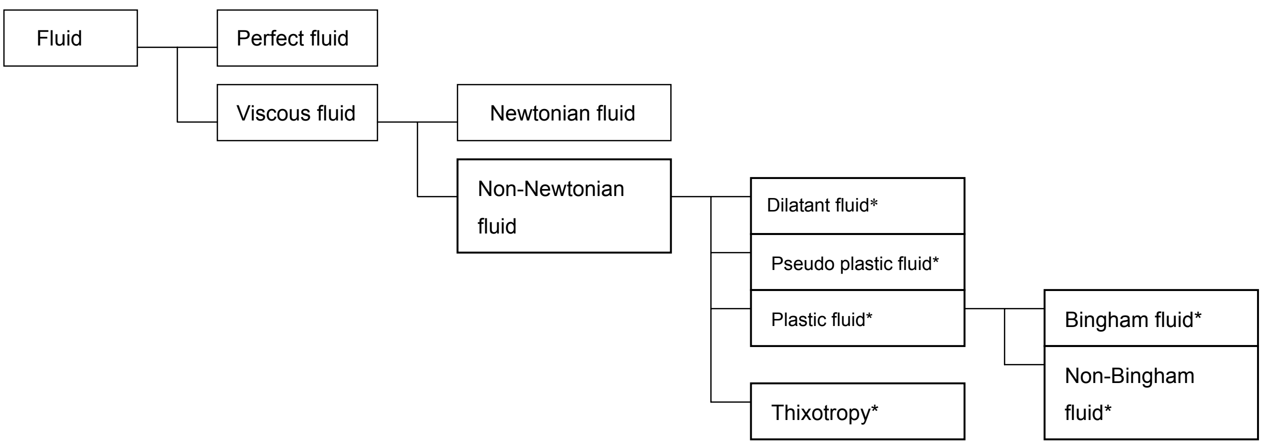
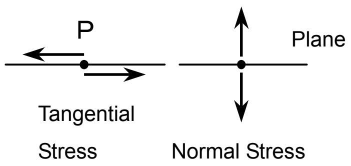


Figure 1 Physical Classification of Fluid

* Please refer to "2. Viscosity".

† Tangential Stress

Where a plane passes through a given point P in a fluid, each part of the fluid on both sides of the plane exert forces on each other. The force (stress) per unit area of the plane is resolved into a tangential component and a normal component; they are called a tangential stress and a normal stress respectively. For example, when it is a resting fluid, the tangential stress is zero and the normal stress exerts pressure.



2. Viscosity

Viscosity, which is also called a viscosity coefficient, is the substance constant indicating the magnitude of the “fluidity” of a fluid. Let’s look at viscosity from a physics point of view in order to understand and define it properly.

As shown in Figure 2, the two plates, board A and board B, are placed parallel to each other and filled with a liquid (fluid). The distance between board A and board B is y_0. Where board A is fixed and board B is being moved parallel to board A at a constant speed of V_0, if the fluid between board A and board B is also in motion parallel to board A and has produced a steady flow, this is called the **Couette flow**.

Where the velocity at a given distance y between board A and board B is V, they are in proportion as shown in Figure 2. Where the slope of the straight line connecting O and P’ is D,

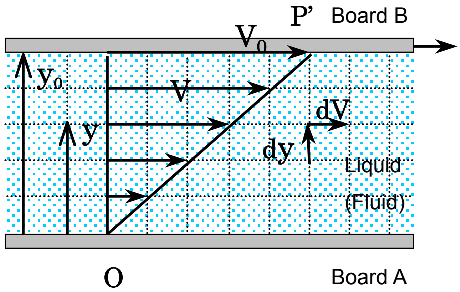


Figure 2 Couette Flow (Newtonian Fluid)

$$\mathbf{D = V/y}$$

Since it equals the increased quantity of the velocity per unit distance, i.e. the velocity gradient,

$$\mathbf{D = dV/dy} \qquad (1)$$

D is called a **shear rate**.

In Figure 2, the liquid layers at distance y and at distance y+dy flow parallel to each other at speed V and at speed V+dV respectively. Because of the difference in the velocities, an internal frictional force will develop between them. The frictional force applied to the unit area of the plane parallel to the flow direction between board A and board B is called a **tangential stress**. This is also known as a **shear stress**.

Where τ stands for a tangential stress, it is proportionate to shear stress D. Where η stands for the proportional constant,

$$\tau = \eta D \text{ (Newton's law of viscosity)} \qquad (2)$$

The equation (2) represents the law known as **Newton's law of viscosity**. Proportional constant η is called **viscosity** or a **viscosity coefficient**.

$$\eta = \tau / D \qquad (3)$$

The fluid subject to this law, whose viscosity η at specific temperature is constant in spite of shear rate D or shear stress τ, is called a **Newtonian fluid**. If shear rate D and shear stress τ are not proportionate, i.e. if viscosity η of the fluid is variable with the quantities of shear rate D or shear stress τ, it is called a **non-Newtonian fluid**. A liquid such as water, alcohol, etc. which is composed of a single substance (molecule) is a Newtonian fluid. On the other hand, a polymer solution, a colloidal solution, etc. is generally a non-Newtonian fluid.

Figure 3 shows the relationship between shear rate D and shear stress τ. As straight line ① shows, where they are in proportion indicating a constant slope of the line, it is a Newtonian fluid. Where θ stands for the slope, viscosity η is represented by the following equation (4);

$$\eta = \tan\theta \qquad (4)$$

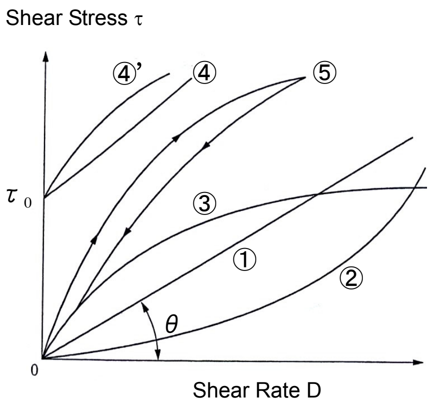


Figure 3 Newtonian Fluid and Non-Newtonian Fluid (Yutaka Matsuyama, Jitsuyo Kogyo Bunseki, 61, The Energy Conservation Center, 2001)

The fluids with fluidities such as indicated by lines ② - ⑤ are non-Newtonian fluids. Viscosity τ/D varies in response to the quantity of shear rate, and the viscosity will not be constant.

Curved line ② shows what is called a **dilatant fluid**, and the viscosity increases as the shear rate increases.
Curved line ③ shows what is called a **pseudo plastic fluid**, and the viscosity decreases as the shear rate increases.
Straight line ④ and curved line ④' show what is called a **plastic fluid,** which will not flow until the quantity of the shear rate becomes equal to or over the shear stress τ_0 (yield stress) of specific criticality after increased from zero. After reaching the yield stress, if the relationship between τ and D shows a straight line such as line ④, it is called a **Bingham fluid**. If it shows a non-straight line such as curved line ④', it is called a **non-Bingham fluid**.
Curved line ⑤ shows what is called **thixotropy**. Hysteresis occurs during the increasing and decreasing processes of the shear rate. This is indicated when a liquid at rest becomes a sol state (colloidal solution) at flow, and then returns to a gel again at rest.

Table 1 below shows typical examples of each type of fluid:

Table 1 Typical examples of fluid type

Type of fluid	Typical example
①Newtonian fluid:	Water, sugar solution, salt solution, alcohol, solvent, glycerin, silicon oil, oil-based (water-based) cosmetics, mercury
②Dilatant fluid:	Starch solution, moist sand (quick sand), suspension (high concentration), clay slurry, paint, chocolate (buttermilk)
③Pseudo plastic fluid:	Colloidal solution, polymer solution, emulsion, lacquer varnish, paint/dye, mayonnaise, sauces, juice, evaporated milk
④Plastic fluid (Bingham fluid) :	Margarine, tomato ketchup, egg white (foam), toothpaste, cream (cosmetics), various slurries (cloudy liquid with solid particle)
(Non-Bingham fluid) :	Print ink, paint, coating, mayonnaise, refined flour of alimentary yam paste, asphalt, blood
⑤Thixotropy:	Solder paste, grease, print ink, clay suspension, tomato ketchup, cocoa, cream (cosmetics)

3. Units of Viscosity

According to the equation (3) aforementioned, viscosity is $\eta = \tau/D$. This is represented by SI units based on the MKS system of units as follows:

(i) Shear stress τ is force per unit area. The unit of force is Newton (N). Therefore the unit of τ is N/m^2 or Pascal [Pa], which is the unit of stress (pressure).

(ii) Shear rate D is defined as dV/dy by the equation (1), and is represented by the unit [s^{-1}], which was given by dividing the unit [m/s] of speed V by the unit [m] of distance y. Therefore, according to (i) and (ii), the unit of viscosity η is [Pa]/ [s^{-1}]=[Pa·s]. [Pa·s] reads "Pascal·second".

(SI unit system) **Unit of viscosity η is [Pa•s]** (5)

On the other hand, according to the CGS system of units, the unit of force is dyne, and the unit of τ is [dyne/cm^2]. Since the unit of shear rate D is [s^{-1}] above, the unit of viscosity η is represented by [dyne/cm^2]/ [s^{-1}]= [dyne·s/cm^2], which is called poise [P].

(CGS unit system) **Unit of viscosity η is [P]** (6)

The relationship (conversion) between SI and CGS units of viscosity η is represented by the equation 1[Pa·s] = 10 [P] because 1 Newton is 1×10^5 dyne, and $1m^2$ is $1\times10^4 cm^2$. Therefore,

1[m Pa•s]=1[cP] (7)

[m Pa•s] and [cP] read "mili-pascal-second" and "centi-poise" respectively.

The result given by dividing viscosity η by density ρ of the liquid is called **kinematic viscosity**, or **kinetic viscosity**, or **dynamic viscosity**.

Where a symbol ν stands for the kinetic viscosity;

Kinetic viscosity $\nu = \eta/\rho$ (8)

SI unit of kinetic viscosity is represented by [m^2/s], which was given by dividing the equation (5) by the unit of density [kg/m^3]. [m^2/s] reads "square-meter-per-second".

On the other hand, using CGS units, it is represented by [cm^2/s], and this unit is called stokes [St].

Therefore, the units of kinetic viscosity are as follows:

SI unit: **[m^2/s]** (9)

CGS unit: **[cm^2/s]=[St]** (10)

Relationship (conversion): **1×10^{-4}[m^2/s]=1[cm^2/s]=1[St]** (11)

Or; **1×10^{-6}[m^2/s]=1[mm^2/s]=1×10^{-2}[St]=1[cSt]** (12)

[cSt] reads centi stokes.

Reference – Viscosity

As shown in Figure 4, where stress τ exerted on board B (inside) of unit area 1 cm^2 is 1[dyne/cm^2] when the distance between board A and board B is 1cm and it is filled with liquid, and only board B is being moved parallel at a speed of 1cm/second (shear rate D = 1[s^{-1}]), according to the equation (3) $\eta = \tau/D$, viscosity η of this liquid is given as 1 poise [P], or according to the equation (7), as 0.1 Pascal second [Pa•s].

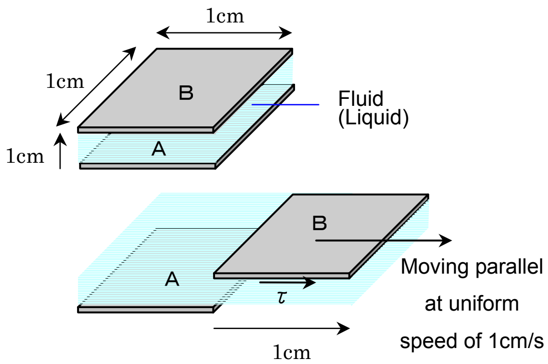


Figure 4 Geometric Definition of Viscosity

Measuring viscosity coefficient is useful for evaluating viscidity. Several types of viscometer have been developed for research and development, or various industries. Viscometers are classified into the following types by the measurement principle. As of today, viscometers 1) to 4) below are standardized as the JIS viscosity measurement method.

1) Vibro viscometer: Measures viscosity by controlling the amplitude of the sensor plates immersed in a sample and measuring the electric current to drive the sensor plates.
2) Rotational viscometer: Measures viscosity by measuring the running torque of the cylindrical rotors immersed in a sample.
3) Capillary viscometer: Obtains viscosity by letting a sample flow inside the capillary and measuring the difference in pressures between both ends of the capillary.
4) Falling-ball viscometer: Obtains viscosity by measuring the time of a cylindrical or spherical object falling through a sample over a specific distance.
5) Cup-type viscometer: Obtains viscosity by measuring the time taken by a sample to flow out of the opening in a container.

1. Vibro Viscometer

As shown in Figure 5, the thin sensor plates are immersed in a sample. When the spring plates are vibrated with a uniform frequency, the amplitude varies in response to the quantity of the frictional force produced by the viscidity between the sensor plates and the sample.
The vibro viscometer controls the driving electric current to vibrate the spring plates in order to develop uniform amplitude. Since the frictional force of viscidity is directly proportional to the viscosity, the driving electric current (driving power) for vibrating the spring plates with a constant frequency to develop uniform amplitude is also directly proportional to the viscosity of each sample.
The vibro viscometer measures the driving electric current to vibrate the sensor plates with a uniform frequency and amplitude, and then the viscosity is given by the positive correlation between the driving electric current and the viscosity.

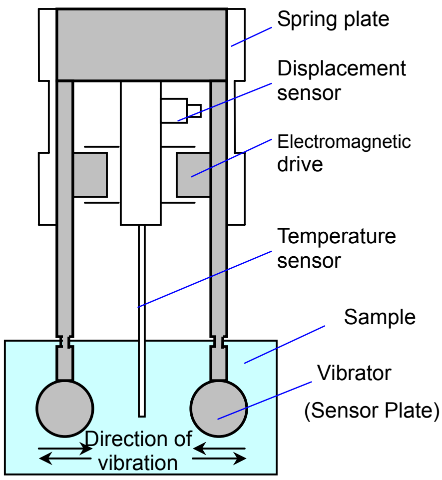


Figure 5 Vibro Viscometer (Detection System)

A&D's vibro viscometer SV series is designed for sensitive measurement of viscosity providing a wide dynamic range and high resolution by vibrating with a frequency of about 30 Hz equivalent to the eigenfrequency (resonance) of the detection system. As a result, the SV series can determine dynamic ranges of viscosity measurement as wide as from 0.3mPa•s to 10,000mPa•s with SV-10 and from 1Pa•s to 100Pa•s with SV-100, and is capable of continuously measuring in these measurement ranges with excellent repeatability (accuracy) and stability. This wide dynamic range enables the measurement of viscosity changes in thixotropic processes during which a liquid turns into gel from sol (colloidal solution), or in the curing processes of resin, adhesive or paint, which cannot be continuously measured with a conventional rotational viscometer.

2. Rotational Viscometer

As shown in Figure 6, a cylindrical rotor is placed in a sample and rotated with a motor at a constant speed. The rotational viscometer employs the measurement method applying the fact that viscosity is directly proportional to a running torque required to develop steady rotating motion. As shown in Figure 6, when the rotation has become steady, the running torques caused by the viscosity and the twist of the spring will be balanced, the twist angle of the spring will be proportional to the viscosity of a sample, and an index of this will be displayed on the scale. Some devices display the digital value of viscosity coefficient converted from running torque.

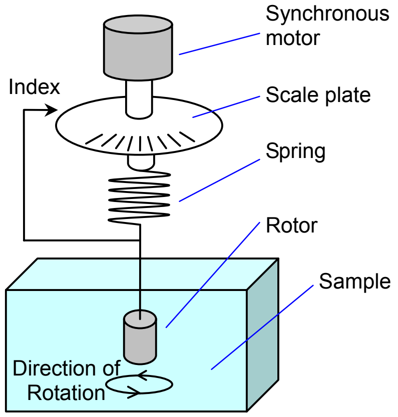


Figure 6 Principle of Rotational Viscometer

The model shown in Figure 6 is called a **single cylindrical rotational viscometer** whose method is the simplest. There is another method called the **coaxial double cylindrical viscometer**, which has outer and inner cylinders with a central axis. This measures viscosity by filling in between both cylinders with a sample fluid and rotating either of them to make a laminar flow.
There is also another called the **torque type viscometer**, which measures viscosity by controlling uniform running torque.

The rotational viscometer is, in principle, a fine measurement method. However, it requires several kinds of rotors in order to cover a wide range of measurement. The measurement range of a single rotor is narrow, and, as a result, the continuity of a measurement will be disturbed and lost when exchanging rotors.
In addition, measurement accuracy is guaranteed only for the full scale, and then errors in measurement are inevitable in the lower viscosity range.
In worst cases, accurate viscosity may not be obtained because viscosity varies accompanied by the gradually rising temperature of a sample after starting the measurement in both lower and higher viscosity ranges. This happens because, in lower viscosity ranges, a larger rotor is required to detect torque more than at a certain level, and, in higher viscosity ranges, a great quantity of kinetic energy caused by a great frictional force is exerted on the rotor.

3. Capillary Viscometer

When the laminar flow of liquid flows through a cylindrical capillary tube, as shown in Figure 7, where symbol Q stands for the volume of flow per unit time (flow rate), 2r for the diameter, L for the length of the capillary tube, P_1 and P_2 for the pressures at the both ends of the capillary tube, and the pressure differential P_1 - P_2 is ΔP, the flow rate Q is directly proportional to the pressure gradient $\Delta P/L$. This phenomenon is called **Poiseuille's law** and represented by the equation (13).

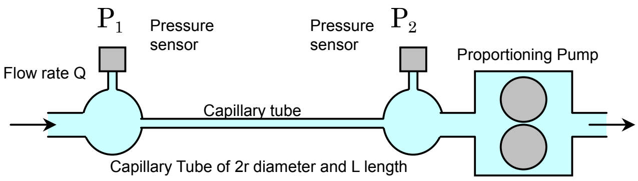


Figure 7 Principle of Capillary Viscometer

$$Q = \frac{\pi r^4}{8\eta} \frac{\Delta P}{L} \qquad (13)$$

From equation (13), viscosity η is represented by equation (14) as follows:

$$\eta = \frac{\pi r^4}{8L} \frac{\Delta P}{Q} \qquad (14)$$

Therefore, with a capillary viscometer that has a structure shown in Figure 7, the viscosity η can be obtained by measuring the flow rate Q of the fluid flowing through the capillary tube and the pressure differential ΔP between both ends of the capillary tube. This measurement method is based on the laws of physics; therefore, the viscosity according to the definition of viscosity can be obtained. This is called the absolute measurement method of viscosity.

There is another type of capillary viscometer made of glass as shown in Figure 8.
Although processing of this capillary tube is not easy, it has rather simple principles and a simple structure. Due to the simplicity of its principles, it has been used since early times and has greatly improved over time. This capillary viscometer can obtain kinetic viscosity ν by measuring time t taken by a certain amount of sample to flow by free-fall through the capillary tube.
Each viscometer is given the viscosity constant C, which was valued by calibrating with Viscosity Standard Fluid.
The measurement of kinetic viscosity with this capillary viscometer is represented by equation (15) below;

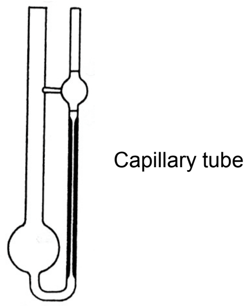


Figure 8 Capillary Viscometer (Free-fall)

$$\nu = Ct \qquad (15)$$

The correlation between kinetic viscosity and viscosity is represented by equation (8) above, so viscosity η is represented by equation (16) measuring density ρ of a sample;

$$\eta = \rho\,\nu = \rho Ct \qquad (16)$$

The principles and structure of the capillary viscometer are simple. However, you need to pay a lot of attention to the measuring operation, which requires many troublesome processes, in order to achieve accurate measurement. For instance, special care is needed when cleaning the inside of the capillary viscometer; before measurement you need to perform ultrasonic cleansing a few times using a cleaning liquid such as benzene and then dry, followed by another ultrasonic cleansing now with acetone and then dry, and finally rinse out using purified water and then dry. Temperature control is also essential because glass is susceptible to thermal expansion/contraction under the influence of temperature, especially in lower viscosity ranges, and it may cause grave errors in measurement. Therefore, measurement requires a lot of care and quite troublesome processes. Besides that, you must measure the density of the measuring sample beforehand because viscosity will be measured by calculating from the measured result acquired from kinetic viscosity.

4. Falling-ball Viscometer

As shown in Figure 9, the falling-ball viscometer measures viscosity by dropping a column- or sphere-shaped rigid body, whose dimensions and density are known, into a sample, and measuring the time taken for it to fall a specific distance. Figure 9 illustrates its principle for the viscosity measurement under the law of free-fall of a rigid body in the gravity field. There is another type of device, which measures traveling time when horizontally transporting a rigid body, such as a piston, in a sample fluid at a constant speed by the force applied by the electromagnetic field.

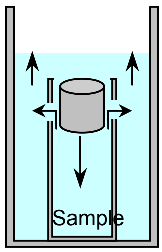


Figure 9 Principle of Falling-ball Viscometer

Unlike the vibro viscometer or the rotational viscometer, the capillary viscometer or the falling-ball viscometer shown in Figures 8 and 9 cannot continuously measure viscosity. It is also impossible to continuously output digital signals of viscosity coefficient or to control data.

5. Cup Type Viscometer

When measuring the viscosity of paint or ink, sometimes the cup type viscometer as shown in Figure 10 may be used. The same method is also employed for adjusting viscosity of coating applied to the exterior of automobile using an electrostatic atomization machine.
As shown in the figure, the cup type viscometer measures time taken by a sample fluid, such as paint or ink, to flow from the opening of a cup. The Ford Cup Viscometer is a typical cup type viscometer and Cup No. 3 for relatively lower viscosity and Cup No. 4 for relatively higher viscosity are often used.

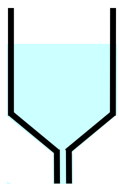


Figure 10 Cup-type Viscometer

Normally, you will measure the time taken by the sample to flow from the opening of a cup using a stopwatch. On the other hand, there is the digital Ford Cup Viscometer, which detects the outflow of the sample with an optical sensor, automatically calculating time necessary to finish continuous outflow, and digitally indicates it in 0.01 seconds.
As well as the capillary viscometer and falling-ball viscometer, the cup type viscometer is not suitable for continuous measurement of viscosity because data as an electrical signal is difficult to obtain for this measurement.

B. Viscosity Standard

1. Viscosity Standard

We know the viscosity of distilled water measured precisely; the viscosity of distilled water is 1.002 mPa•s (kinetic viscosity 1.0038 mm^2/s) at 20.00°C at 1 atm, and this is the primary viscosity standard in Japan.
There are Viscosity Standard Fluids for calibrating viscometers, which are standardized by the Japanese Industrial Standard, JIS Z8809, as shown in the following.

2. Viscosity Standard Fluid

As shown in Table 2, based on the coefficient of kinetic viscosity at 20°C as the reference value, the Japanese Industrial Standard, JIS Z8809, standardizes thirteen types of Viscosity Standard Fluids.
Please note that local suppliers may supply Viscosity Standard Fluids for each country.

Table 2 Viscosity Standard Fluid in Japan

Type	Kinetic viscosity [mm^2/s]				Viscosity [mPa•s]			
	Ref.	Approximate value			Approximate value			
	20℃	25℃	30℃	40℃	20℃	25℃	30℃	40℃
JS 2.5	2.5	—	2.1	1.8	2.0	—	1.6	1.4
JS 5	5.0	—	3.9	3.2	4.1	—	3.2	2.5
JS 10	10	—	7.4	5.7	8.4	—	6.1	4.6
JS 20	20	—	14	10	17	—	11	8.2
JS 50	50	—	32	21	43	—	27	18
JS 100	100	—	59	38	86	—	51	32
JS 200	200	—	110	66	170	—	95	56
JS 500	500	—	260	150	440	—	230	130
JS 1000	1000	—	500	270	890	—	430	230
JS 2000	2000	—	940	480	1800	—	820	420
JS 14000	14000	—	5500	2400	12000	—	4800	2100
JS 52000	52000	—	20000	8500	46000	—	18000	7500
JS 160000	160000	100000	—	—	140000	90000	—	—

These Viscosity Standard Fluids have traceability to the national standard. Some of them are registered with COMAR, the database for certified reference materials, which is associated with the international standards. Those are easy to come by here in Japan; Nippon Grease Co., Ltd., one of the major vendors of Viscosity Standard Fluids, supplies Viscometer Standard Fluids with traceability to the national standard, which are calibrated by the National Institute of Advanced Industrial Science and Technology.
We need to be careful about handling of Viscosity Standard Fluid. As shown in Table 2, viscosity depends greatly on temperature. If the temperature has changed by 1°C, the viscosity will change by about 2%-10%. Therefore, when calibrating a viscometer, we need to precisely control the temperature.
There are the other handling cautions given by JIS Z8809 as follows;

(1) Seal the container of the Viscosity Standard Fluid and keep it at room temperature avoiding heat and light.
(2) Never return used Viscosity Standard Fluid to the original container.
(3) Avoid reusing Viscosity Standard Fluid. It is advisable to use it up as soon as possible once opened.

Water (distilled water) is a substance easy to come by or handle, and is also internationally recognized as standard. Water can be used as a convenient standard fluid in lower viscosity. When using water as a standard fluid, we need to purify the water to destroy all impurities in it, and generally use purified water or distilled water. Purified water is also used for a number of cleanings after thoroughly cleaning the inside of the sample container using cleaning agent to remove any remaining impurities. Before measuring, we need to clean the sensor unit, which is to be immersed into a sample in case there is any residue on it.

As shown in Table 3 and Figure 11, the viscosity of water greatly varies in response to temperature changes. It holds true to every liquid and gas; in the case of water, the viscosity of 1.002 mPa•s will change to 1.792 mPa•s at 0°C, or to 0.282 mPa•s at 100°C. It produces a difference of 2% – 3% in viscosity when the temperature changes by 1°C. Even if we manage to keep the temperature of the sample (water) within ±1°C, in the end error of ±5% in the measured value may occur due to complex error factors such as the properties of water, an operator's operational mistake, or a congenital error in the viscometer.

Table 3 Viscosity and Kinetic Viscosity (1 atm)

Temp. t (°C)	Visco. η (mPa•s)	Kine. Visco. ν(mm²/s)	Temp. t (°C)	Visco. η (mPa•s)	Kine. Visco. ν(mm²/s)
0	1.792	1.792	40	0.653	0.658
5	1.520	1.520	50	0.548	0.554
10	1.307	1.307	60	0.467	0.475
15	1.138	1.139	70	0.404	0.413
20	1.002	1.0038	80	0.355	0.365
25	0.890	0.893	90	0.315	0.326
30	0.797	0.801	100	0.282	0.295

JIS Z8803

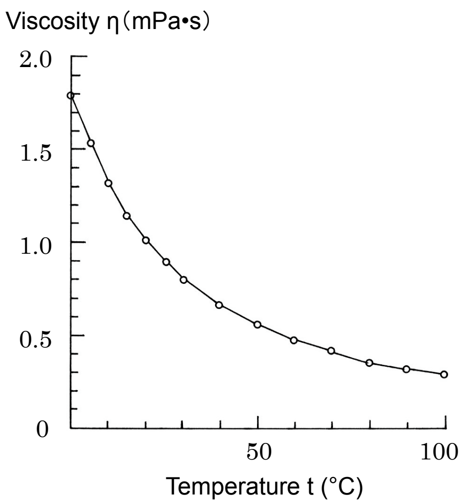


Figure 11 Correlation between Viscosity and Temperature of Water (1 atm)

C. Calibration

No.	Question	Answer
1	Can a user perform viscosity coefficient calibration?	Yes. Users can calibrate the SV Series using Viscosity Standard Fluids (aforementioned) or a liquid whose viscosity is under your control. When calibrating your viscometer, since the viscosity of Viscosity Standard Fluid depends on the temperature, before inputting a calibration value, you need to make a temperature correction of the viscosity coefficient of the standard fluid in response to the temperature displayed while measuring a sample. As to Viscosity Standard Fluids, temperature correction values are listed on the Certificate or Certificate of Measurement. If they are not attached, please ask the manufacturer of the Viscosity Standard Fluid. - The Vibro Viscometer SV series requires no exchange of sensor plates for the viscosity ranges as wide as from 0.3 mPa·s to 10,000 mPa·s with the SV-10 and from 1Pa·s to 100 Pa·s with the SV-100. For calibration, just prepare several kinds of standard fluids so that you can do it yourself. This will save you more time and money for calibration/control of viscosity, compared to the rotational viscometer. - Viscosity Standard Fluid standardized by JIS is composed of hydrocarbon mineral oil, which is susceptible to temperature changes or other environmental factors. You are recommended to use a chemical-synthesized Viscosity Standard Fluid, such as silicon oil, which is more stable in environmental changes.
2	Which is adopted for viscosity calibration, one-point calibration or two-point calibration?	Both one-point and two-point calibrations are available for A&D's vibro viscometer SV series. You can choose either of the one-point input (span correction) or the two-point input (zero/span corrections) of calibration values. We recommend the two-point calibration if the intended measuring range is wide. With the SV-10, it is possible to perform simple calibration around 1mPa･s using purified water. It enables easy calibration with automatic temperature compensation for viscosity value according to the temperature of the purified water.
3	Has the vibro viscometer been accredited by the JCSS ?	Vibro viscometers, such as the SV series, have been accredited by the JCSS. The capillary viscometer and the rotational viscometers have also received accreditation. The JCSS (Japan Calibration Service System) ensures reliable calibration services and measurement reliability, which conforms to national measurement standards.

No.	Question	Answer
4	Is a Traceability System Diagram and Certificate available?	Yes. A Traceability System Diagram and Certificate on viscosity and temperature can be issued. The SV series is calibrated on delivery for viscosity with standard fluids for calibration. On issuance of a Certificate, inspections using JS Standard Liquids defined by JIS will be given; the SV-10 will be inspected with Standard Liquids JS2.5 and JS1000 and the SV-100 with JS2000 (or silicone oil) and JS14000. Temperature inspection is given at a fixed temperature around room temperature. Please ask for a Certificate on the placement of your order. (Issuance of Certificate will be charged.) If you need a Certificate for the product after purchase, it is necessary to send the whole SV unit to us.
5	What is the measurement accuracy of the viscometer? What does 1% repeatability mean?	Repeatability is the variation in measurement results when repeating measurements of the same sample under the same conditions. In statistics, this is called the standard deviation. For the SV series, it means when measuring the same sample under the same conditions the variation (repeatability) in measurement results (measured values) does not surpass 1% as the standard deviation. - Example of 1% standard deviation: When repeating measurement of a liquid of 100mPa･s viscosity, values between 99mPa･s and 101mPa･s will be indicated 67 times out of 100.
6	What does repeatability with respect to "measured value" mean?	The quantity of actual error greatly differs between the repeatability with respect to a measured value and the repeatability with respect to a full scale. The SV series, whose repeatability is based on "measured value", can achieve a high repeatability with the principle of the Sine-wave Vibration Method assuring a repeatability of 1% of a measured value.

Examples of actual error where the full scale ranges 10000 mPa·s

Method	Measured viscosity		
	10 mPa·s	100 mPa·s	1000 mPa·s
SV Method (1% of measured value)	0.1 mPa·s	1 mPa·s	10 mPa·s
Other method (In case of 0.2% of full scale)	20 mPa·s	20 mPa·s	20 mPa·s

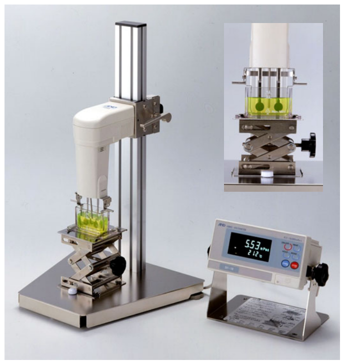
Reference
- Symbols

Table 4. Greek Characters.

Α	α	alpha	Η	η	eta	Ν	ν	nu	Τ	τ	tau
Β	β	beta	Θ	θ, ϑ	theta	Ξ	ξ	xi	Υ	υ	upsilon
Γ	γ	gamma	Ι	ι	iota	Ο	ο	omicron	Φ	φ, ϕ	phi
Δ	δ	delta	Κ	κ	keppa	Π	π	pi	Χ	χ	chi
Ε	ε	epsilon	Λ	λ	lambda	Ρ	ρ	rho	Ψ	ψ	psi
Ζ	ζ	zeta	Μ	μ	mu	Σ	σ, ς	sigma	Ω	ω	omega

■Product

A. Mechanism and Features of Sine-wave Vibro Viscometer SV Series



The Sine-wave Vibro Viscometer SV Series has a unit to detect the viscosity of a sample, which is composed of two thin sensor plates as shown in Figure 12. It drives the sensor plates to vibrate at a uniform sine-wave vibration rate in a reverse phase like a tuning fork. The sensor plates are driven with the electromagnetic force of the same frequency as eigenfrequency (resonance), which is the characteristic of each structure, in order to resonate the measuring system. This usage of resonance is the most prominent feature of this viscometer. When the detection unit vibrates, it produces a sizable magnitude of reaction force on the supporting unit of the sensor plates via the spring plates. However, since each sensor plate is driven in reverse phase against each other at the same vibration frequency/amplitude in order to cancel the reaction force, it enables the user to obtain stable sine-wave vibration.

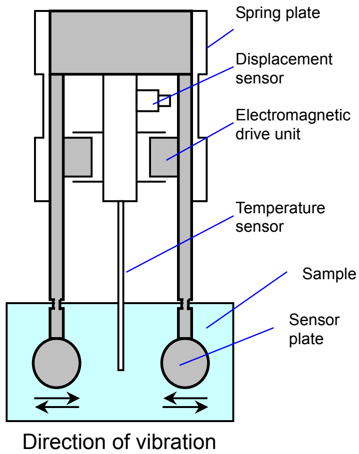


Figure 12 Viscosity Detection Unit (Vibration System)

The electromagnetic drive unit controls the vibration of the sensor plates in a sample at uniform amplitude, utilizing the resonance of the detection unit. The driving electric current as an exciting force will be detected as the magnitude of the viscidity, which is present between the sensor plates and the sample. The viscosity coefficient is given by the correlation (Figure 13) between the driving electric current and the magnitude of viscidity (viscosity coefficient).

The advantages of resonating the measuring and detection systems are as follows;

1) Resonance of the detection unit allows viscosity detection with high sensitivity in lower viscosity range and also to effectively acquire a driving force with just a small amount of electric current. Thus, it is possible to measure viscosity while maintaining a wide dynamic range and high resolution.

2) The inertial force and restitutive force of the sensitive plates are cancelled by each other to be in proportion, thus the exciting force (driving electric current) is influenced only by the magnitude of viscidity (viscosity). (The parameter of viscosity alone can be extracted.)

3) The vibration system of the sensor plates is not affected by the inertial and restitutive forces, thus it is possible to measure rapid changes in viscosity of a sample while quickly tracking it.

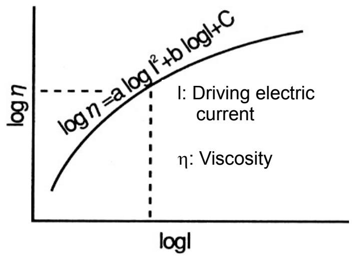


Figure 13 Correlation between Electromagnetic Drive Unit and Driving Electric Current

Furthermore, since the surface areas of the detection unit and sensor plates of SV Series are small, and they are driven with much lower frequency (30Hz) compared to that of a conventional vibro viscometer (several kHz), the SV Series boasts the following features;

1. Measures viscosity in real time in response to changes in viscosity of a sample, while measuring simultaneously the temperature of the sample in real time. Thus correlation between the temperature change and the viscosity can be measured.
2. The newly developed SV method (tuning-fork type) achieves accuracy with repeatability of as high as 1% in viscosity measurement.
3. No need to exchange sensor plates during continuous measurement in the wide ranges of viscosity from as low as 0.3mPa•s (SV-10) / 1Pa•s (SV-100) to as high as 10,000mPa•s (SV-10) / 1Pa•s (SV-100). (In the case of the rotational viscometer, several kinds of rotors are required, and continuity of viscosity measurement is disturbed and lost when exchanging them.)

4. Since the surface area/thermal capacity of the viscosity detection unit (sensor plates) is small, the temperatures of a sample and the sensor plates will reach thermal equilibrium in a very short time to achieve accurate temperature measurement. (In the case of the rotational viscometer, since the surface area/thermal capacity of the rotors is large, it takes several minutes to achieve this.)
5. Continuous measurement of viscosity is possible for a long period because the small thermal capacity of the sensor plates causes relatively minor interference to the temperature of a measuring sample.
6. The thin sensor plates are employed to avoid deforming a sample's structure in order to measure viscosity changes of the sample in a stable condition. Even viscosity of a non-Newtonian fluid can be measured with high repeatability by utilizing eigenfrequency (resonance).
7. A gel sample with bubbles can also be measured in a stable condition. The frequency of the sensor plates at as low as 30Hz, with small amplitude, does not disperse fine bubbles in a sample.
8. The two sensor plates interact to make it possible to measure the viscosity of a stirring or flowing sample. (The rotational viscometer cannot measure such a sample because of interferences of the rotating direction and current direction.)
9. Since a sample in a flowing state can be measured, viscosity measurement on the production line is made possible by installing a bypass overflow tank. The laboratory and production line can share identical data management.
10. Changes in properties of a sample can be continuously measured. Since it has a high resolution and no inertia instability of sensor plates, changes in interfacial properties such as cloud point or wettability can be observed from changes in viscosity.
11. WinCT-Viscosity, Windows Communication Tools Software, can be used with the SV Series. You can create real time graphs of data regarding viscosity and temperature as shown in Figure 14 with this software.

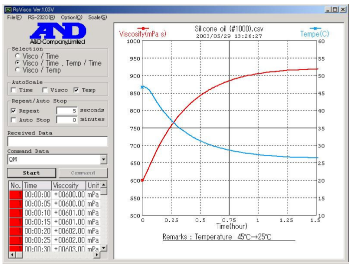


Figure 14 Real Time Display of Measured Data (WinCT-Viscosity)

No.	Question	Answer
7	How does the SV series operate?	It uses the SV method (the Sine-wave Vibro Viscometer). Please see “Product A. Mechanism and Features of Sine-wave Vibro Viscometer SV Series” for more details.
8	Why are there two sensor plates?	This is to stabilize the vibration properties of the detection unit. They are vibrated with the sine-wave frequency of 30 Hz, which is equal to the eigenfrequency (resonance) characteristic of each structure. It achieves accurate measurement by resonating the whole measurement system. A single sensor plate has a sizable reaction force produced on its supporting unit via the spring plate. In order to cancel this force, another sensor plate is vibrated in a reversal phase at the same frequency/amplitude. The reaction forces of the sensor plates are cancelled out by each other; therefore making a very stable vibration measurement system possible. Please see “Product A. Mechanism and Features of Sine-wave Vibro Viscometer SV Series” for the details.
9	Is its data compatible with that of the rotational viscometer (B type)?	Regarding a Newtonian fluid, yes. In the case of a non-Newtonian fluid, sometimes it is not compatible due to the difference in the shear rate particular to each measurement device. If it is not compatible, the data obtained from each device needs to be managed individually or the coefficient needs to be taken into account. Generally, it is effective to adopt a method, which enables accurate measurement in a short measurement time, for improvements of quality and productivity in the future.
10	How should we interpret different obtained values from that of the rotational viscometer (B type)?	Regarding a non-Newtonian fluid, data that is compatible with a cone plate rotational viscometer is obtainable. As to viscometers in general, it is recognized that, if the measurement method or measurement conditions were different, the measured results will be different. To compare several measurement methods, the repeatability of measured results is the key evaluation criteria. It is guaranteed that the SV series achieves 1% repeatability of measured values through the wide range from 0.3mPa･s to 10,000mPa･s with SV-10 and from 1Pa･s to 100Pa･s with SV-100, which a conventional viscometer has never achieved.

11	What magnitude of shear rate does the SV series have?	Regarding a non-Newtonian fluid, the shear rate is not proportional to the shear stress, and therefore a viscosity evaluation cannot be made without determining the value of the shear rate or the shear stress. The SV series measures viscosity at constant shear rate. The velocity (shear rate) of the sensor plates keeps periodically circulating from zero to peak because sine-wave* vibration is utilized. The shear rates obtained from the driving force of the sensor plates in response to the viscosity value of a Newtonian fluid measured with Viscosity Standard Fluid are as follows; *SV-10 and SV-100 vibrate with sine-wave of frequency 30Hz and amplitude approx. 0.2mm (approx. 0.4mm peak-to-peak) and of frequency 30Hz and amplitude approx. 0.1mm (approx. 0.2mm peak-to-peak) respectively.

●SV-10

Viscosity coefficient [mPa•s]	Shear rate (max.) [1/s]	Shear rate (effective value) [1/s]
1	590	420
10	130	92
100	42	30
1000	17	12
10000	10	7

●SV-100

Viscosity coefficient [Pa•s]	Shear rate (max.) [1/s]	Shear rate (effective value) [1/s]
1	11.4	8.1
10	8.6	6.1
100	7.4	5.0

C. Measuring Viscosity

No.	*Question*	*Answer*
12	How long does it take to measure?	The initial viscosity coefficient will be indicated 15 seconds after starting the measurement. After that, measured values will be displayed in real time in response to the changes in viscosity. With the SV Series, the viscosity changes of a sample can be very quickly tracked in a stable condition by virtue of its compact measurement system; the sensor unit (sensor plates), whose surface area and mass are small, make only small shifts and thus reach thermal equilibrium with the temperature of a sample in just seconds.
13	What amount of sample is necessary for a measurement?	35 ml to 45 ml. Compared to the rotational viscometer (B type), it can measure with a lesser amount.

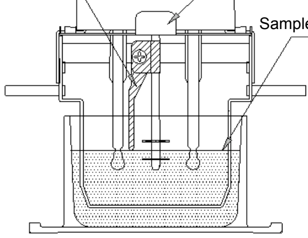
<table>
<tr><td>14</td><td>What repeatability can it achieve?</td><td>Repeatability of 1% is achievable when repeating measurements of the same sample under the same condition. High repeatability is realized for the whole measuring range to obtain stable measured values. Moreover, since its operation is easier than other methods, it allows a user who is not a specialist to repeat a measurement a number of times and obtain a stable result each time.
A sequence of changes in temperature of a heterogeneous substance such as a composite can be measured as well as changes in the properties of matter and the viscosity properties of a non-Newtonian fluid.</td></tr>
<tr><td>15</td><td>Is the measurement unit convertible?</td><td>1. The unit of viscosity coefficient can be switched between mPa・s*/Pa・s and cP*/P. *Only SV-10
2. The unit of temperature can be switched between °C and °F.</td></tr>
<tr><td>16</td><td>What is the minimum display (resolution)?</td><td>●When the unit mPa・s or Pa・s is selected
<table>
<tr><td></td><td colspan="2">SV-10</td><td>SV-100</td></tr>
<tr><td>Viscosity (mPa•s)</td><td>Min. unit (mPa•s)</td><td>Min. unit (Pa·s)</td><td>Min. unit (Pa·s)</td></tr>
<tr><td>0.3～10</td><td>0.01</td><td>0.0001</td><td>–</td></tr>
<tr><td>10～100</td><td>0.1</td><td>0.0001</td><td>–</td></tr>
<tr><td>100～1000</td><td>1</td><td>0.001</td><td>–</td></tr>
<tr><td>1000～10000</td><td>10*1</td><td>0.01</td><td>0.01</td></tr>
<tr><td>10000～100000</td><td>–</td><td>–</td><td>0.1</td></tr>
</table>
*1 The unit changes to Pa•s.
●When cP or P is selected
<table>
<tr><td></td><td colspan="2">SV-10</td><td>SV-100</td></tr>
<tr><td>Viscosity (cP)</td><td>Min. unit (cP)</td><td>Min. unit (P)</td><td>Min. unit (P)</td></tr>
<tr><td>0.3～10</td><td>0.01</td><td>0.0001</td><td>–</td></tr>
<tr><td>10～100</td><td>0.1</td><td>0.001</td><td>–</td></tr>
<tr><td>100～1000</td><td>1</td><td>0.01</td><td>–</td></tr>
<tr><td>1000～10000</td><td>10*2</td><td>0.1</td><td>0.1</td></tr>
<tr><td>10000～100000</td><td>–</td><td>–</td><td>1</td></tr>
</table>
*2 The unit changes to P.</td></tr>
</table>

No.	Question	Answer
17	Is it necessary to exchange sensors or parts for each measuring range?	No. Measuring ranges of SV-10 and SV-100 are as wide as from 0.3mPa·s to 10000mPa·s and 1Pa·s to 100Pa·s respectively, so there is no need to exchange sensors for the full ranges. Therefore, even a process of violent changes in viscosity, such as where a sol turns into a gel, can be continuously measured without disrupting the sequence of data. With a rotational viscometer, it is difficult to track the changes of properties of matter in a wide range like the above, because a single rotor can only measure viscosity for a narrow range. Wide range and continuous measurement with the SV Series will help develop new materials or functional materials in the research field.
18	Up to what temperature can a sample be measured?	The measuring range is from 0°C to 160°C. The heat resistance temperature of the accessory sample cup (plastic) is about 120°C, and so it is usable for any measurement of a sample at 100°C or lower.
19	Can the temperature change of a sample be measured simultaneously with viscosity change?	The SV series is equipped with a temperature sensor in the detection unit (immersed in a sample) enabling simultaneous measurement of temperature of a sample during viscosity measurement. There is no need to prepare a thermometer yourself. Values of viscosity and temperature will be simultaneously indicated on the display unit of the SV Series, so the temperature of a sample can be monitored in real-time during measurement. The correlation between changes in temperature and viscosity can be tracked in real-time as well. The SV Series can detect accurate temperature immediately because the temperatures of a sample and the detection unit (sensor plates) with small surface area/thermal capacity can reach the thermal equilibrium in a short time. The SV Series can be connected to a PC. The accessory software "*WinCT-Viscosity*" enables you to monitor the progress of changes in viscosity and temperature in real-time during measurement using graphs and numerical values. Measured values can be saved in a file (CSV format), and can be converted into an Excel format to produce graphs to suit your application.
20	Is it possible to measure viscosity at a constant temperature?	Yes. You can measure viscosity at a given temperature by using the optional Water Jacket (AX-SV-37) and a constant heat water tank (commercially available). Therefore, you do not have to worry about viscosity changes in response to temperature while controlling the viscosity of a sample.

No.	Question	Answer
21	How can I measure the viscosity change while changing the temperature of a sample?	1. It is possible to measure viscosity while changing temperature by using the optional water jacket (AX-SV-37) and a constant temperature controller (commercially available). It is suited for measurement while adjusting to given temperatures or at a temperature below room temperature. 2. The easiest way is to measure the cooling process of a preheated sample by leaving it in the sample cup. You can also use a heater to heat the sample cup, but please make sure that the temperature of the heater's surface does not exceed 120°C. We recommend using a beaker when it exceeds 100°C. 3. The viscosity/temperature data can be transmitted during measurement to a PC using the standard accessory software "*WinCT-Viscosity*". As a result, obtaining viscosity/temperature data in numerical values is possible while simultaneously displaying a graph in real time. "*WinCT-Viscosity*" has a function to create a graph with the temperature reading indicated along the x-axis and the viscosity along the y-axis, thus temperature coefficient of viscosity can be checked visually.
22	What refrigerant should be used for the Water Jacket (AX-SV-37)?	The basic refrigerant is water. However, at around 0℃ or 100℃, water is not sufficient by itself as a refrigerant. Isopropyl alcohol should be used at around 0℃ and silicon oil at around 100℃. Please note that some refrigerants may corrode the polycarbonate Water Jacket. (We strongly advise against using ethanol, methanol and general antifreeze liquid (which contains additives that can penetrate plastic).)
23	If a solvent sample is measured, will the accessory Sample Cup melt?	The Sample Cup is made of polycarbonate, so it may become disfigured or melt if a solvent is used. To avoid this, please use the optional Glass Sample Cup (AX-SV-35) instead or a glass beaker, etc. (commercially available). A 100 ml or larger beaker can be used. However, the sensor unit protector should be removed before measurement when a 100 ml beaker is used.
24	Can I use a different container to the accessory Sample Cups provided?	The SV series has been calibrated for viscosity with the Sample Cup (polycarbonate, volume 35ml - 40ml). If measuring absolute value of high viscosity over 1000mPa·s, you are strongly recommended to calibrate with the container provided.
25	What materials are the sensor plates and the temperature sensors, which come in contact with a sample, made of?	They are made of gold-coated stainless steel (SUS304). They will not be corroded with a normal organic solvent, and are not easily corroded with an acid or basic (alkaline) solution sample. In order to make them withstand prolonged use and prevent the occurrence of errors, cleanse (wipe off) with a counteractive solution to neutralize.
26	Is it possible to measure the viscosity of a non-Newtonian fluid?	Yes. Since the thin sensor plates of the detection unit scarcely deform the structure of a sample, it is possible to make a stable measurement of a non-Newtonian fluid with high repeatability quickly responding to the change in viscosity of the sample.

No.	Question	Answer
27	Can I obtain accurate results even from a sample of low viscosity?	1. Yes. The SV-10 offers you stable measurement results from a sample of low viscosity. You can measure viscosity as low as 0.3 mPa･s and above with no need for exchanging sensors or installing a special adapter/accessories for low viscosity measurement. Accurate evaluation of the correlation between temperature and viscosity is also made possible by immediately measuring the temperature of a sample. Applying this feature, the SV-10 offers an objective evaluation method for evaluating “smoothness and pleasantness to throat” of low viscosity liquid such as soft drinks, wines, sakes, beers, or sparkling liquor by representing it in numerical values that were previously difficult to achieve. 2. In other methods, measuring viscosity in the range as low as 50 mPa･s or lower has caused many difficulties due to the interferences caused by energy in the measurement systems, the sensitivities, or measurement principles. On the other hand, the SV-10 can easily measure a sample of low viscosity while tracking the temperature of the sample.
28	Is it possible to measure the viscosity of a sample in a flow state?	Yes. A unique feature of the Sine-wave Vibro Viscometer SV is its ability to continuously measure the viscosity of a flowing sample. It is possible to measure the viscosity of a flowing sample in the range of 300 mPa･s or lower if it can be stirred with a stirrer. However, please note that if the surface of a sample fluid is flowing and unstable, the surface level will vary and a stable measurement will not be possible. In the case of a non-Newtonian fluid, its viscosity changes as its flow state changes, so please make sure to measure at a constant flowing rate. A flowing sample in a production line can be continuously measured by installing a bypass overflow tank in order to keep the surface of the fluid level.

No.	Question	Answer
29	How can I obtain rigorous absolute values of viscosity?	The Vibro Viscometer SV series is set (adjusted) on delivery to indicate the viscosity coefficient of a fluid assuming its density is 1. The viscosity coefficient on the display represents a product of multiplication of the viscosity and density based on measurement principles. In order to obtain the absolute value of viscosity, please divide the measured viscosity value of a sample by its density at that time. Example: where a sample was measured at temperature T, the absolute value will be obtained as follows; 1) Viscosity is displayed as 73.6 (mPa･s). 2) Specific gravity of the sample at temperature T is 0.856. 3) The absolute value of viscosity η_M is 73.6/0.856=85.98 (mPa•s). If the density of a sample is uncertain, please measure the density (specific gravity) of the sample beforehand with an electronic balance and density measuring kit. It can be easily obtained with A&D's analytical electric balance GR Series or general electronic balance GX/GF Series and Density Determination Kit. *In this case, measure the viscosity under the same temperature condition as the density (specific gravity) was measured.
30	Is it possible to measure kinetic viscosity?	No. The Vibro Viscometer cannot directly measure it. You can calculate it by obtaining the absolute value η_M as in Q&A28 and dividing it once again by the density of a sample.

No.	Question	Answer
31	To what level should the surface of a sample fluid reach? What is the affect on the measuring value if the surface level varies?	1. There is a narrow area just above the round-shaped part of the sensor plate. Adjust to level these narrow areas of the sensor plates with the surface of the sample fluid as you can see in the figure on the right. If either of the right or left sensor plates cannot be leveled with the surface of the fluid, please adjust the two leveling feet at the rear of the main body in order to eliminate body tilt. If your product is equipped with a fluid level adjustment plate, the tip of the fluid level adjustment panel points to the center of the narrow area of the sensor plate. Raise the level of the fluid surface until the tip of the fluid level adjustment panel is in contact with the fluid.  2. If the surface of the fluid changes by 1 mm, the SV-10 will measure a viscosity change of about 5%. After repeating initial measurements, you will be able to level the surface of the sample fluid. In due course, error occurrence in the leveling of a sample's surface will fall below ±1%, when repeating measurements of the same sample under the same conditions. With the SV-100, if the surface of the fluid changes by 1 mm, the viscosity will change by about 15%. However, error in leveling of the surface will fall below ±1% using the fluid level adjustment panel. 3. With samples of high viscosity, if the sample surface is uneven the viscosity measurement value may be affected. Be sure to even out the surface with a spatula, etc. 4. During a viscosity measurement over a long period the surface level of a sample fluid may lower due to evaporation. Be sure to adjust the level regularly.

No.	Question	Answer
32	Is there anything I should pay attention to regarding measurement of sample changes over a long period of time?	1. Lowering of Liquid Surface Level Due to Evaporation In viscosity measurement over a long period, the liquid surface level of some samples may lower because of evaporation. In this case adjust the surface level regularly during measurement. If the sample surface level has lowered but is still above the round parts of the sensor plates, since a drop in viscosity value along with change of the surface level appears almost linearly, lowering of surface level can be corrected. 2. Change of Sample Over Time For example, in continuous measurement of tap water, bubbles appear on the surfaces of the sensor plates and container. This happens because air is formed in tap water under water pressure. Since the SV series viscometer detects torque produced between a sample fluid and the sensor plates, bubbles or solids acquired on the surfaces during measurement will be measured as a change in viscosity. As a result, a gradual rise in viscosity will be observed. It is possible to minimize bubbles generated by using pure water or purified water. If measurement of pure water, purified water, etc. is continued for about a week, bacterial thread or algae contained in the air will multiply in the water and such conditions will allow algae to grow on the sensor plates. A rise in water temperature will be measured in this case. In measurement over a long period such unexpected sample changes could be recorded. 3. Separation in a Sample In measurement of mixed fluids such as sol or gel, liquid and solid will separate over time. In such cases, it will be observed that the liquid component gathers around the sensor plates and thus viscosity lowers. Be sure to use a stirrer to agitate the fluid to make it uniform, except in cases of sedimentation measurement of solid component in fluid. (The optional Water Jacket can be attached with the stirrer.) In measurement of heating and cooling, a sample fluid may be separated during heating and then the supernatant portion may be coagulate like jelly after cooling. In cases like this, it is possible to maintain uniformity of the fluid to some extent by agitating with a stirrer. 4. Fixed Contamination on the Sensor Plates Please note that any fluid or hardened residues contaminating the sensor plates above the surface level of sample fluid will have adverse impacts on the sensor plates and interfere with accurate viscosity measurement. Regular maintenance is necessary, especially in the case of continuous use.

D. Collection and Output of Data

No.	*Question*	*Answer*
33	Is it possible to print out measured results? Is it possible to collect and save measured data?	Yes. Output printing and data collection are possible. 1. By connecting the RS-232C equipped as standard to the compact printer AD-8121B (optional), results can be printed. With the AD-8121B, statistical calculation of the viscosity measurement results or change in viscosity (numerical values) per length of time can be printed. Please use the AD-8121B accessory cable for connection. 2. Connecting to a PC, the standard accessory software Windows Communication Tools "*WinCT-Viscosity*" enables the monitoring of the progress of changes in viscosity and temperature in real time during measurement with graphs and numerical values. The measured data can be saved in a file (CSV format) and converted into an Excel file in order to use graphing functions to obtain data and graphs suited your purpose/application. * Please see "Application A. Data Analysis" for the details on the features of the software and examples of display of "*WinCT-Viscosity*".

■Application

A. Data Analysis

1. Windows Communication Tools "*WinCT-Viscosity*"

1. Windows Communication Tools "*WinCT-Viscosity*"
Via RS232C, this software enables A&D's Sine-wave Vibro Viscometer SV series to display the progress of measurement in real time on a PC or easily transmit the measured results (data) to save or analyze. The CD-ROM of *WinCT-Viscometer* is equipped as a standard accessory of the Viscometer SV Series.

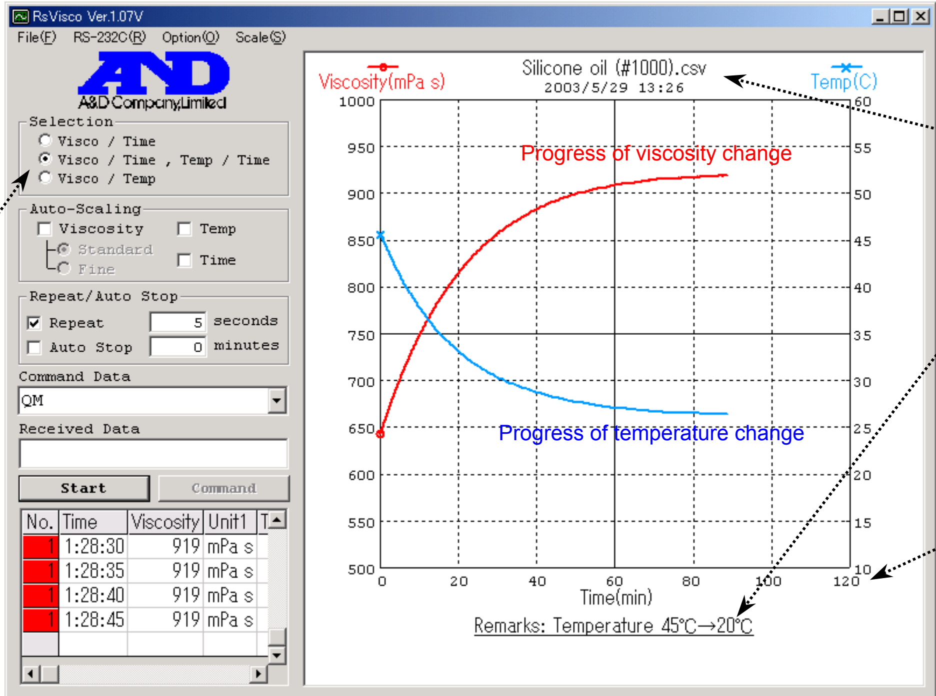
Windows Communication Tools *WinCT-Viscosity* includes three software functions as follows;
- RsVisco: Graphing software to create graphs of the measured results and the progress of viscosity measurement.
- RsCom: Data transmission/reception software
- ReKey: Data transfer software

Software	Content
●RsVisco	1. Creates real-time graphs of data received from A&D's Sine-wave Vibro Viscometer SV series via the RS-232C. Progress of change in viscosity during measurement can be monitored on a graph. Temperature data can also be simultaneously displayed, and a graph displaying temperature and viscosity can be monitored in real time. 2. The following three types of graphs are provided to choose from; □Viscosity (Y axis) – Time (X axis) □Viscosity/Temperature (Y axis) – Time (X axis) □Viscosity (Y axis) – Temperature (X axis) 3. Graphs can be overlaid with different measurements (in 10 colors). 4. Measured data can be saved in a CSV format file. 5. Displayed graph can be printed via a PC.
●RsCom	Send and receive data with a PC via RS-232C. This software is capable of controlling the Viscometer SV series. 1) Recorded data can be saved in a text file. 2) Received data can be printed with a printer via a PC. 3) Simultaneous communication with multiple viscometers connected to ports of a PC is possible. (Multiprocessing)
●RsKey	1. Data output from the SV series can be imported to general application software (Microsoft Excel, etc.) via the RS-232C. It is useful to process data using other application software. 2. Data output from the SV series Viscometer can be automatically input to application software as if it were input with a keyboard. Transmits to spreadsheet software (Excel), word processing software (Word, memo pad), or other various kinds of application software.

(1) Example of RsVisco Display

RsVisco is software, which makes it possible to read the measured data (CSV file) and create a graph representing the viscosity measurement in real-time as shown in the figures below. Figures 15 and 16 show the graphs representing viscosity changes of silicon oil (Newtonian fluid) measured at room temperature while leaving it cooling down from about 45°C to 25°C. In Figure 15, the graph shows the elapsed time plotted along the x-axis and the viscosity (left) and the temperature (right) plotted along the y-axis. In Figure 16, the same data is represented by plotting the temperature along the x-axis and the viscosity along the y-axis. The linearity of the correlation between the changes in viscosity in response to the changes in temperature is clearly represented.

A graph can be selected from the three.



Title can be freely input or edited on the display.

Remarks can be freely input or edited on the display.

Maximum/ minimum values on the x/y-axis can be freely input or changed on the display.

Figure 15 Example of Measurement Display of Silicon Oil (SV-10)

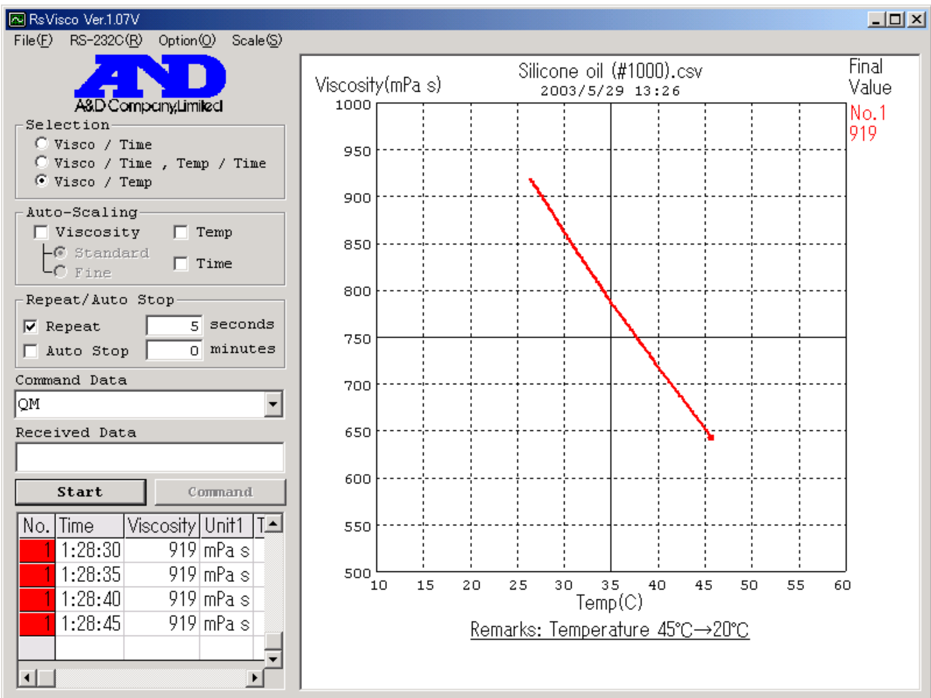


Figure 16 Correlation between Viscosity Change in Response to Temperature Change of Silicon Oil

(2) Example of Viscosity Measurement of Purified Water

Figure 17 shows the result of SV-10 measurement of purified water while cooling naturally after heating to approx. 40℃. Figure 18 is a graph plotting temperature along the horizontal axis and viscosity along the vertical axis. In Figure 18, measurement values are indicated in red and theoretical values in green. The graph indicates that the viscosity of purified water is accurately measured. The SV-10 enables correct viscosity measurement of samples of low viscosity.

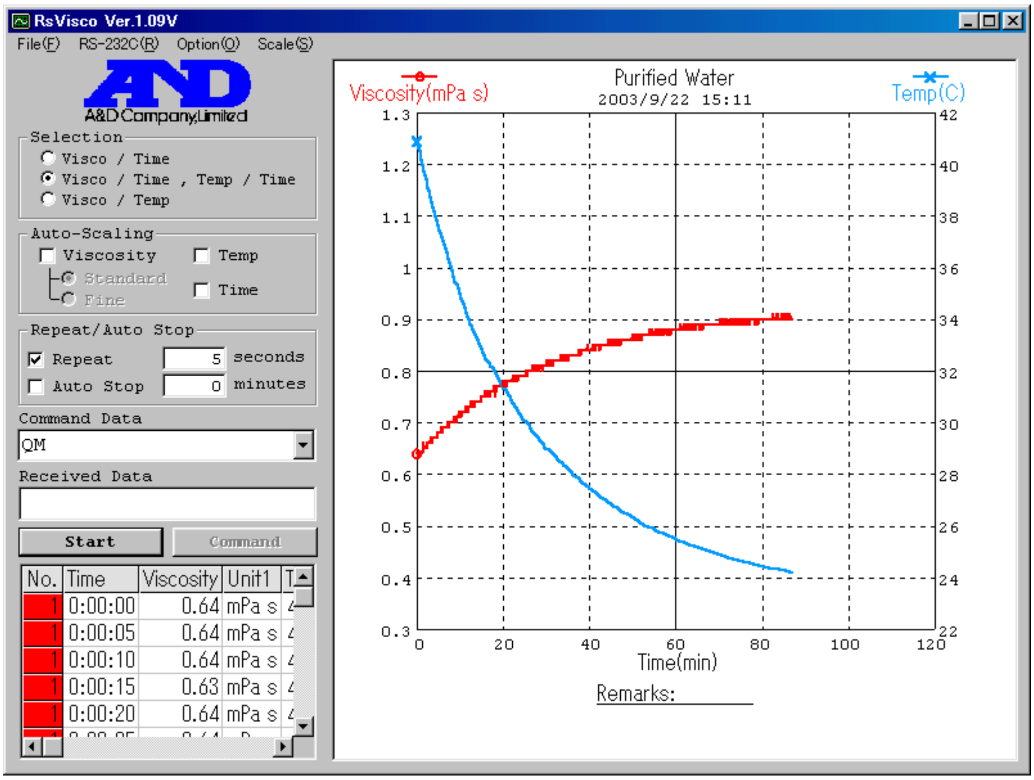


Figure 17 Example of Viscosity Measurement of purified water (SV-10)

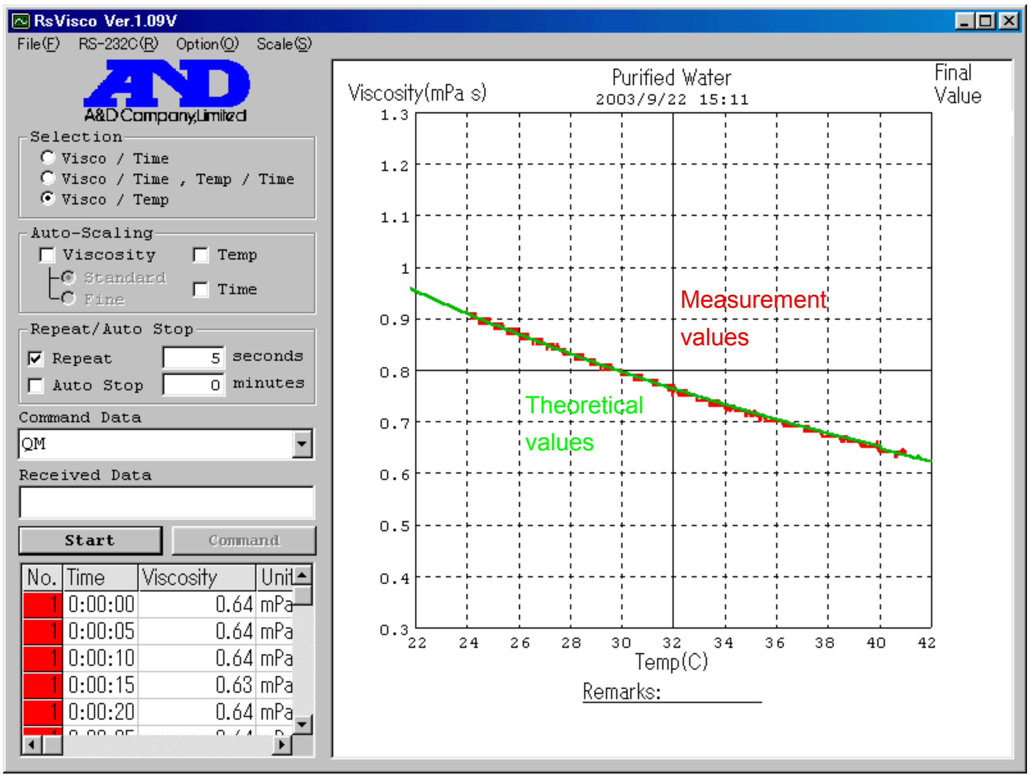


Figure 18 Example of Viscosity Measurement of purified water (SV-10)

(3) Example of Viscosity Measurement of Water-based Paint

Figure 19 shows a graph representing the measurement results of a water-based varnish at room temperature under fixed conditions. This sample shows a stable viscosity despite the elapsed time.
Figure 20 represents the measurement results of a water-based paint (black) at room temperature under fixed conditions.

After starting the measurement, this sample shows a gradually decreasing tendency (thixotropy). To evaluate the viscosity of a sample such as this, we find the time when the decreasing tendency becomes slow experimentally. We can evaluate the viscosity value from the time.

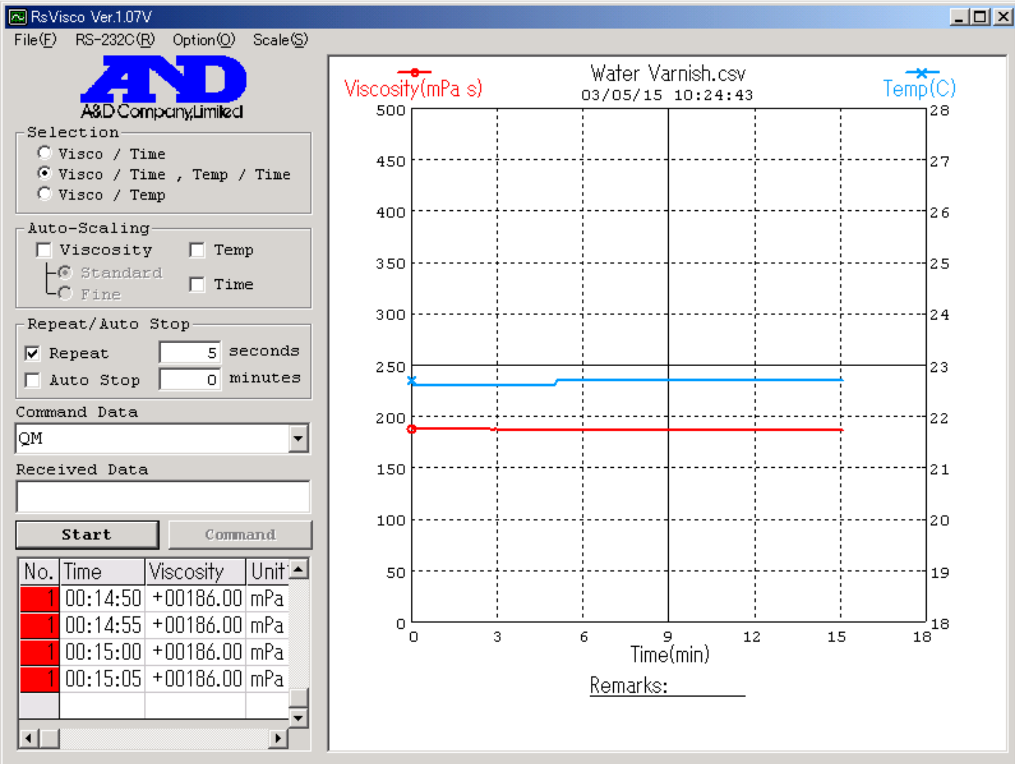


Figure 19 Example of Viscosity Measurement of Water-based Varnish (SV-10)

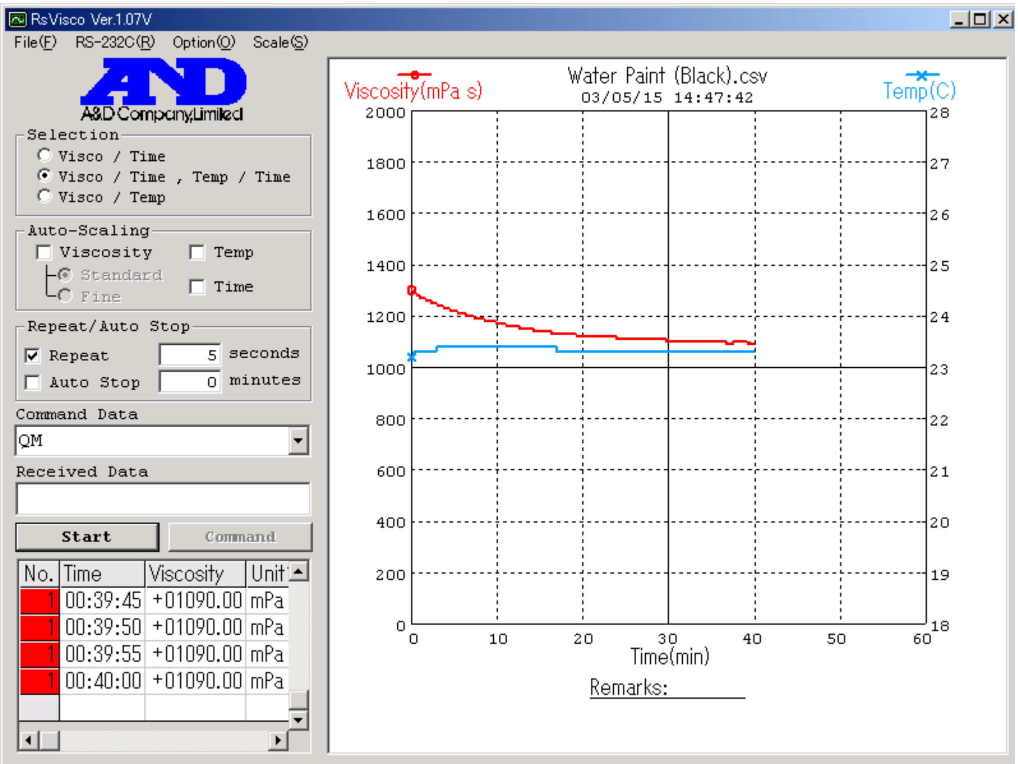


Figure 20 Example of Viscosity Measurement of Water-based Paint (SV-10)

(4) Viscosity Measurement of Food

Figures 21 and 22 show graphs representing the measurement results of the viscosity of egg white while heating it from room temperature to about 80°C. The behavior of egg white rapidly coagulating over 60°C is clearly illustrated. The graphs precisely show the properties of protein (albumin), which is the main component (composition) of egg white.

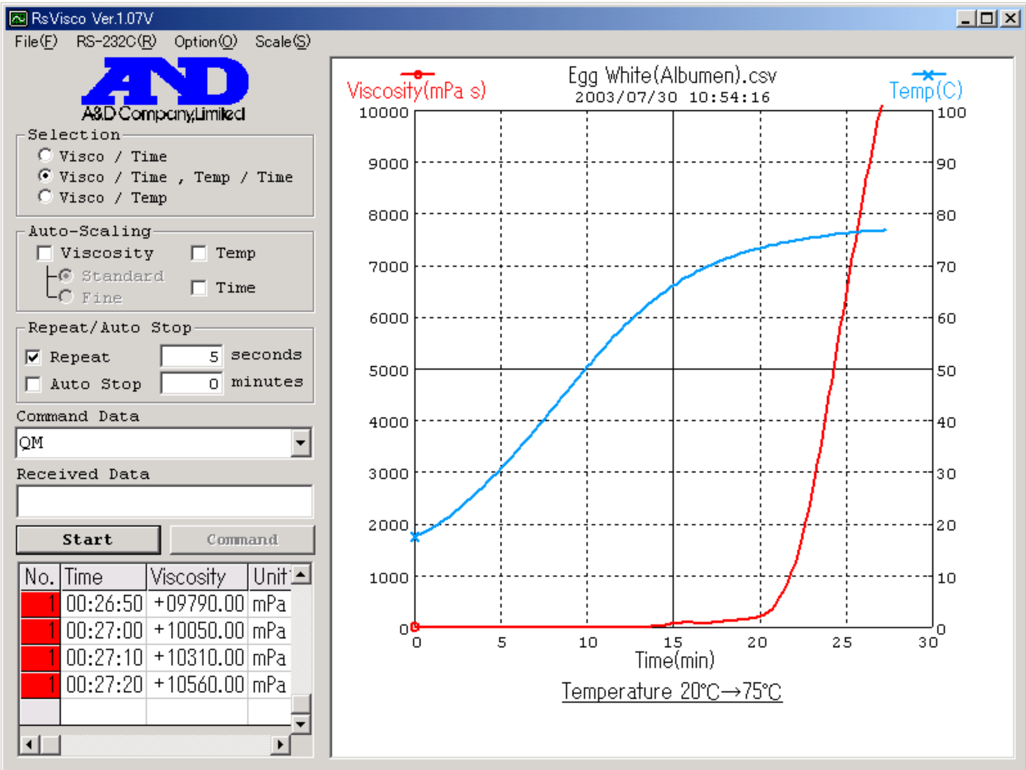


Figure 21 Example of Viscosity Measurement of Egg White (SV-10)

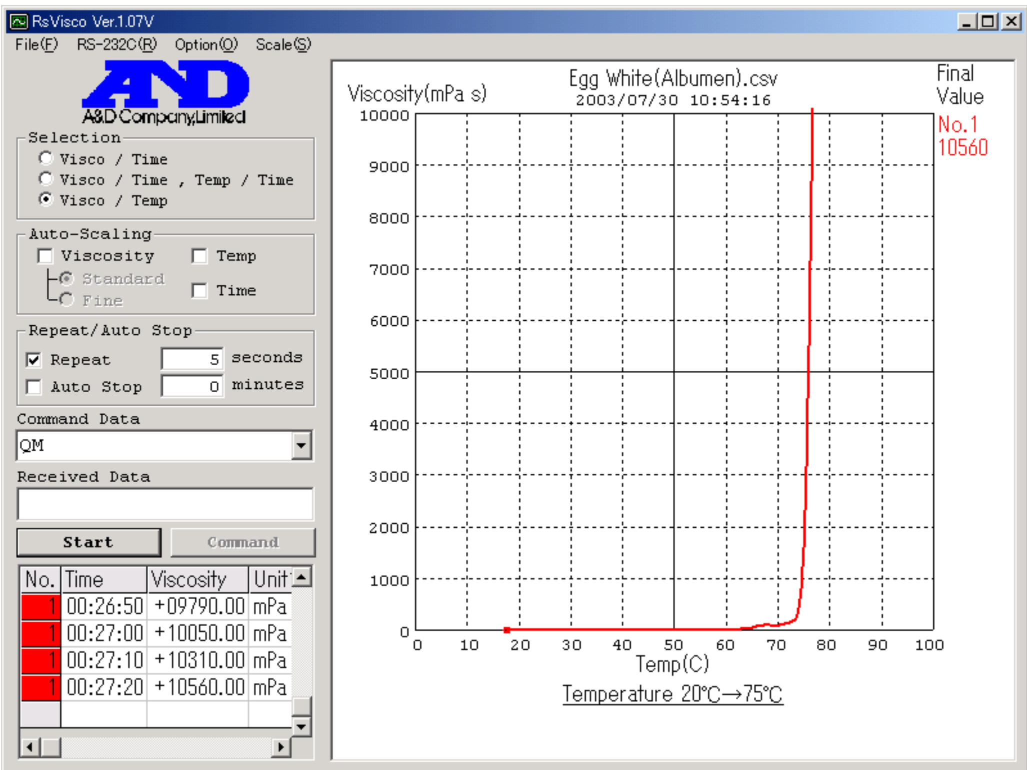


Figure 22 Increasing Process of Viscosity of Egg White with Temperature Increase (SV-10)

Figures 23 and 24 show graphs representing the measurement results of the viscosity of egg white, shown in Figures 21 and 22, by indicating with logarithmic scale on the y-axes (viscosity). We can observe, especially in Figure 24, that when the temperature was 60°C or lower, the viscosity of egg white decreased as the temperature increased, like a common liquid does, but once it surpassed 60°C, the viscosity increased rapidly as its protein coagulated. The SV Series Vibro Viscometer can capture precise dynamic changes in viscosity as well as small changes peculiar to a sample (matter). As you can see below, *WinCT-Viscosity (RsVisco)* can indicate a logarithmic axis on the viscosity axis so as to clearly present the changes in viscosity of a wide range or of non-linearity.

Indicates a logarithmic axis as viscosity axis.

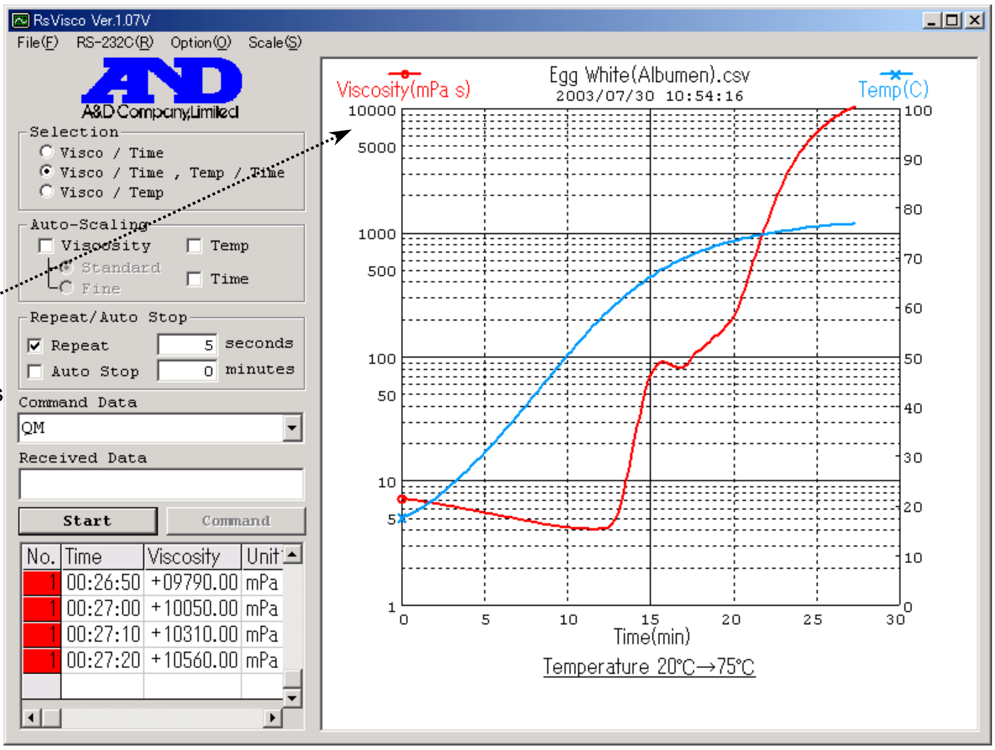


Figure 23 Example of Viscosity Measurement of Egg White (Log scale on the viscosity axis)

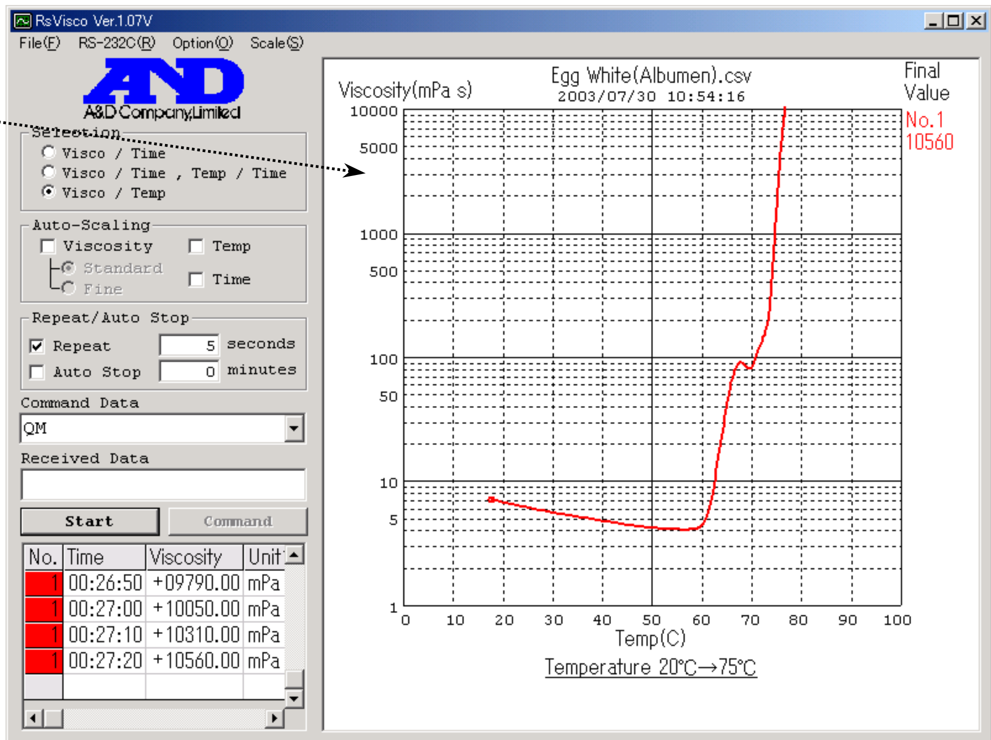
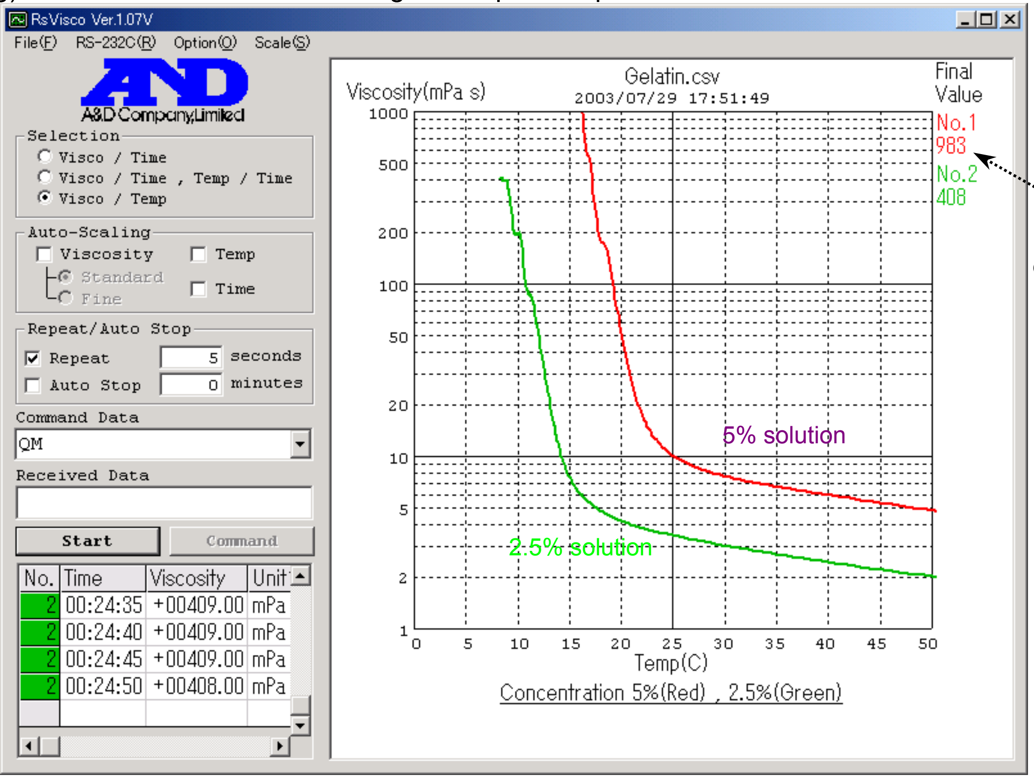


Figure 24 Progress of Viscosity Increase in Response to Temperature Increase of Egg White (Log scale on the viscosity axis)

Figure 25 shows an example of viscosity measurement of 2.5% and 5% gelatin solutions while varying the temperatures. The temperature is plotted along the x-axis and the viscosity along y-axis (log). We can observe that the coagulation point depends on the concentration of the solution.



Multiple measurements can be overlaid on a graph. (10 colors available)

Figure 25 Example of Viscosity Measurement of Gelatin of Different Concentration (Viscosity Axis Log Scale)

Figure 26 is a graph representing the measured result of custard pudding at approx. 20°C. Four samples (3 good samples and 1 failure sample) were measured. The upper three lines (red, light blue and light green) are of good samples and the lower line (purple) is of the sample, which was evaluated as a failure. As we can see, the evaluation made based on one's own experience is now possible to present with values by measuring viscosity with the SV-10.

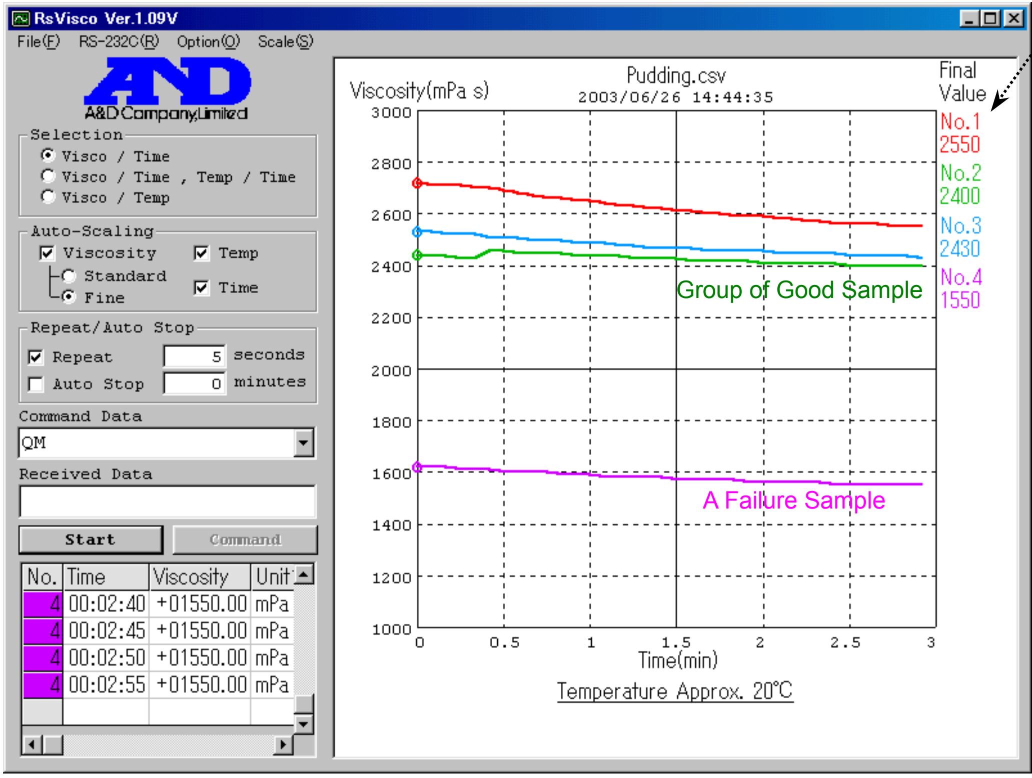


Figure 26 Example of Viscosity Measurement of Custard Pudding

Figure 27 shows a graph representing the measured result of Worcester sauce under fixed conditions (room temperature).
We can see from the SV-10 measurement that Worcester sauce shows a stable viscosity in response to the elapsed time.

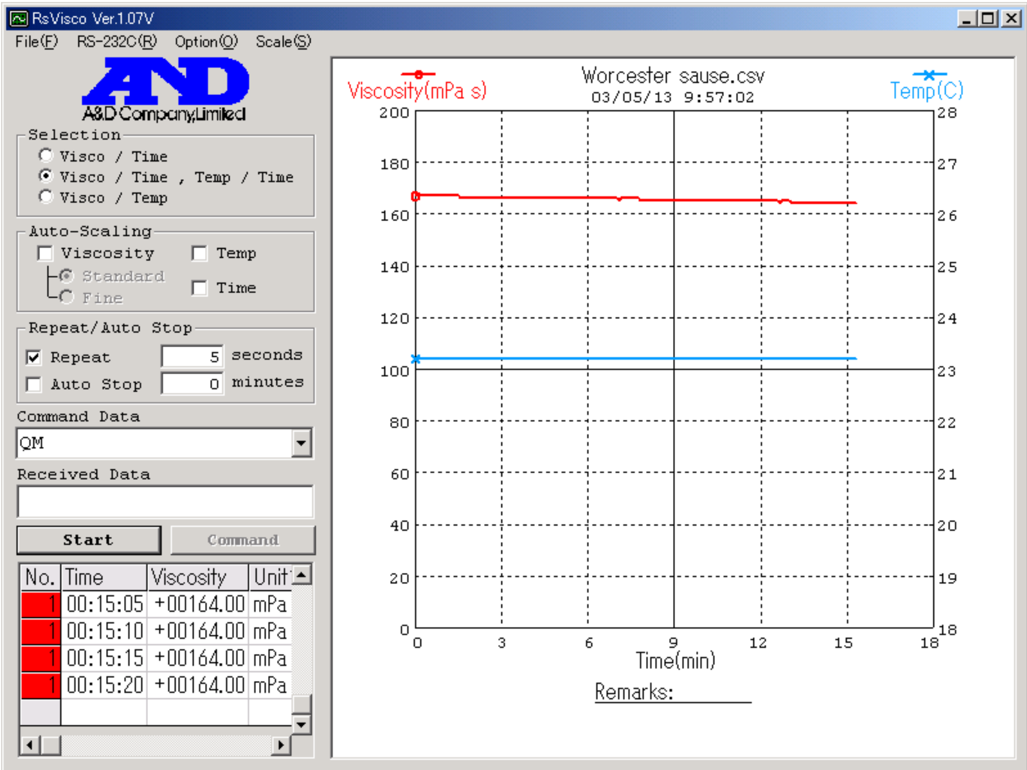


Figure 27 Example of Viscosity Measurement of Worcester Sauce (SV-10)

(5) Viscosity Measurement Examples of Industrial Products

Figures 28 and 29 show the results of SV-10 measurement in the natural cooling process of 100cc gasoline engine oil after heating to about 110℃. Engine oil is generally evaluated with viscosities at 40℃ and 100℃. In the measurements, the viscosities were 7.64mPa•s at 100℃ and 45.4mPa•s at 40℃. The SV series can measure the process of temperature change, so you can easily find out the viscosity at a specific temperature.

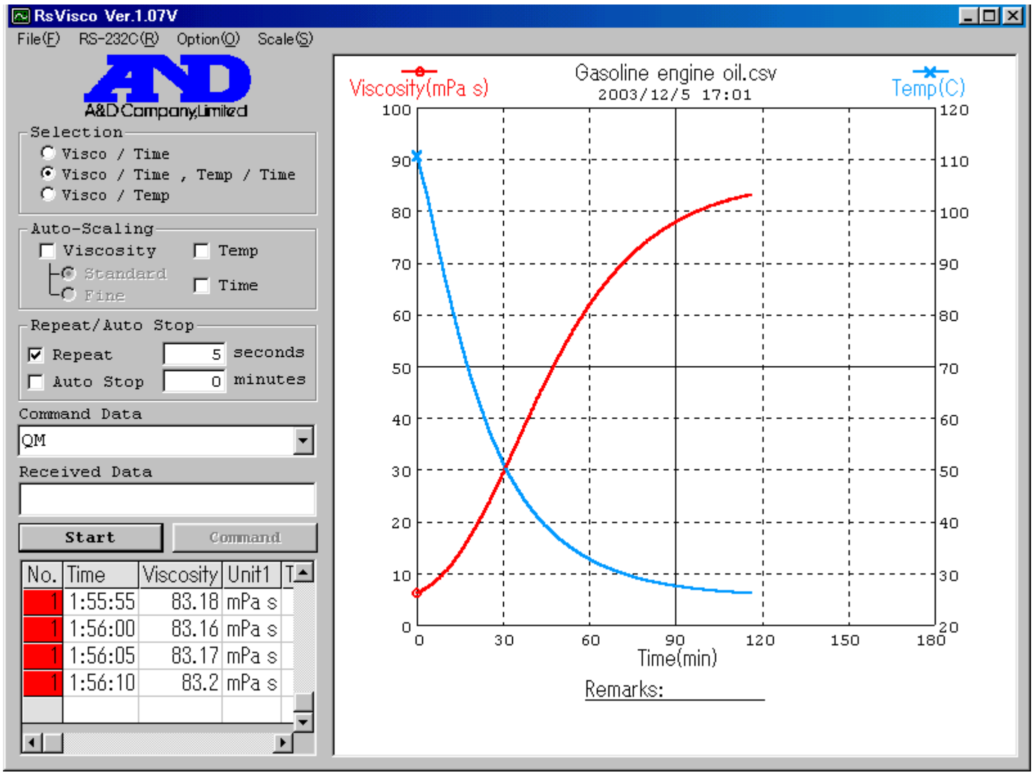


Figure 28 Viscosity Measurement Example of Gasoline Engine Oil (SV-10)

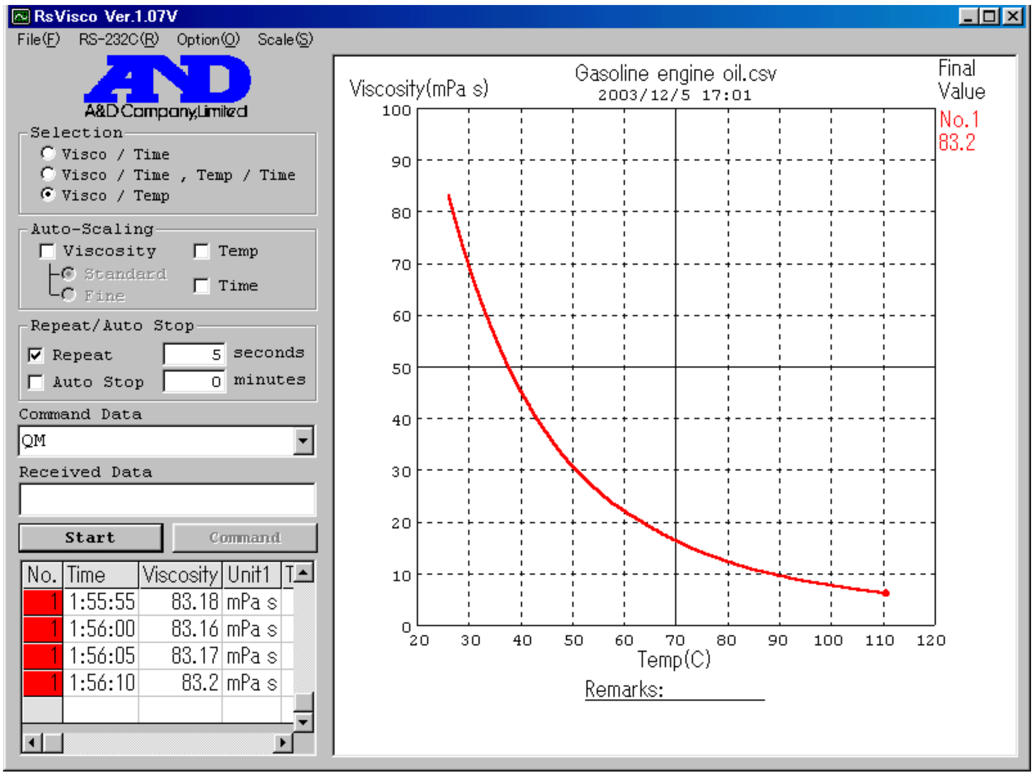


Figure 29 Correlation between Viscosity Change and Temperature Change of Gasoline Engine Oil

Figure 30 shows the SV-10 measurement results of 3 types of semiconductor abrasive. The SV-10 can measure even a fluid of low viscosity and determine the original viscosity and degradation of abrasive. Figure 31 shows the results of SV-10 measurement of plaster in the curing process.
Mixture ratios of 67%, 60%, and 50% of plaster with water (weight ratio), were measured. It shows that the curing time differs according to the mixture ratio.

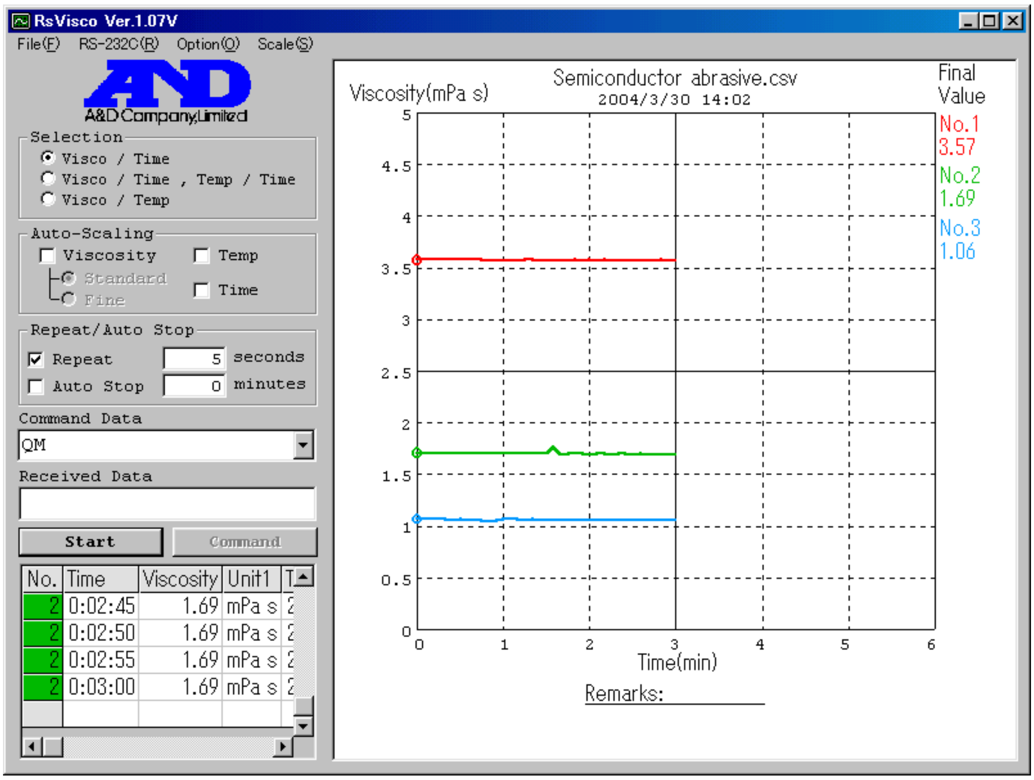


Figure 30 Measurement Example of Semiconductor Abrasive (SV-10)

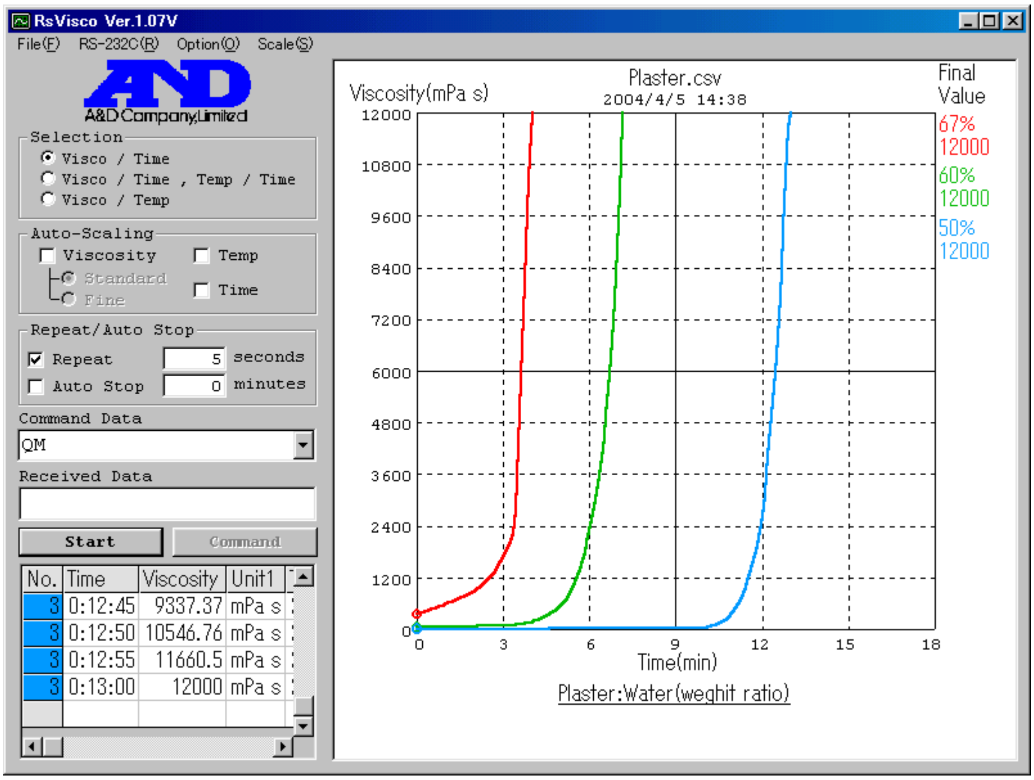


Figure 31 Measurement Example of Curing Process of Plaster (SV-10)

Figure 32 shows the results of SV-10 measurement in the natural cooling process of solder flux in paste form after heating to melt. The temperature – viscosity graph shows that the gelation point is approx. 68℃.

Figure 33 shows the result of SV-100 measurement of silicon adhesive in the curing process. Although it took about one day to cure, we can observe the curing process of the adhesive because the SV series can continuously measure over a long period of time.

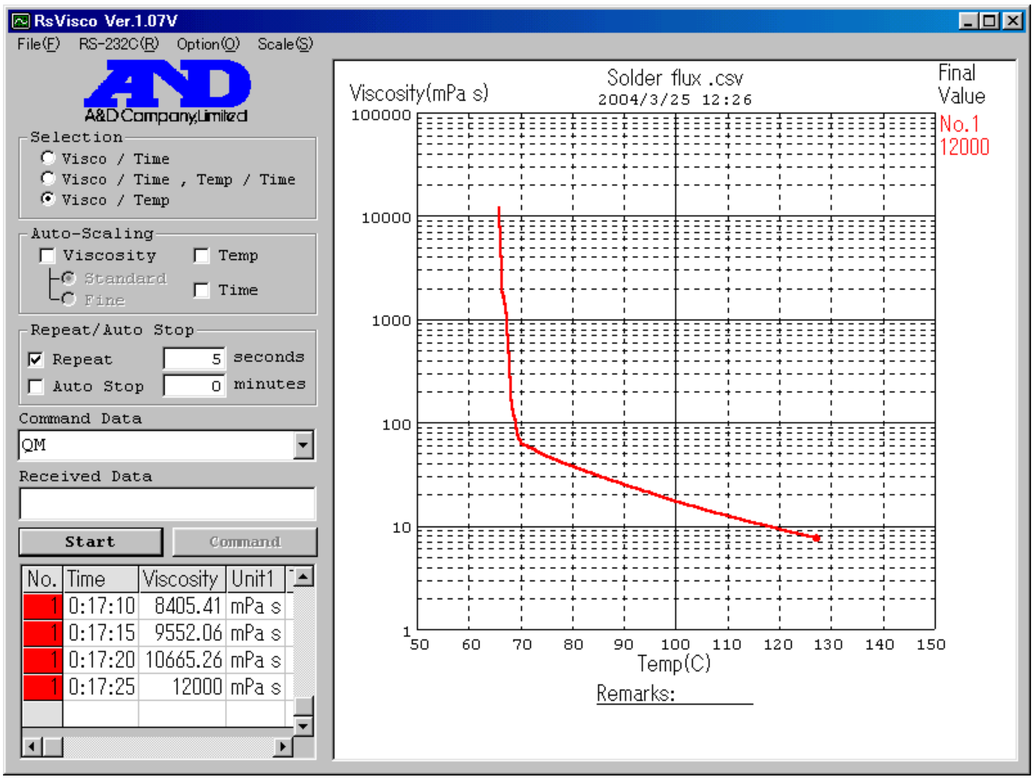


Figure 32 Measurement Example of Gelation Point of Solder Flux (SV-10)

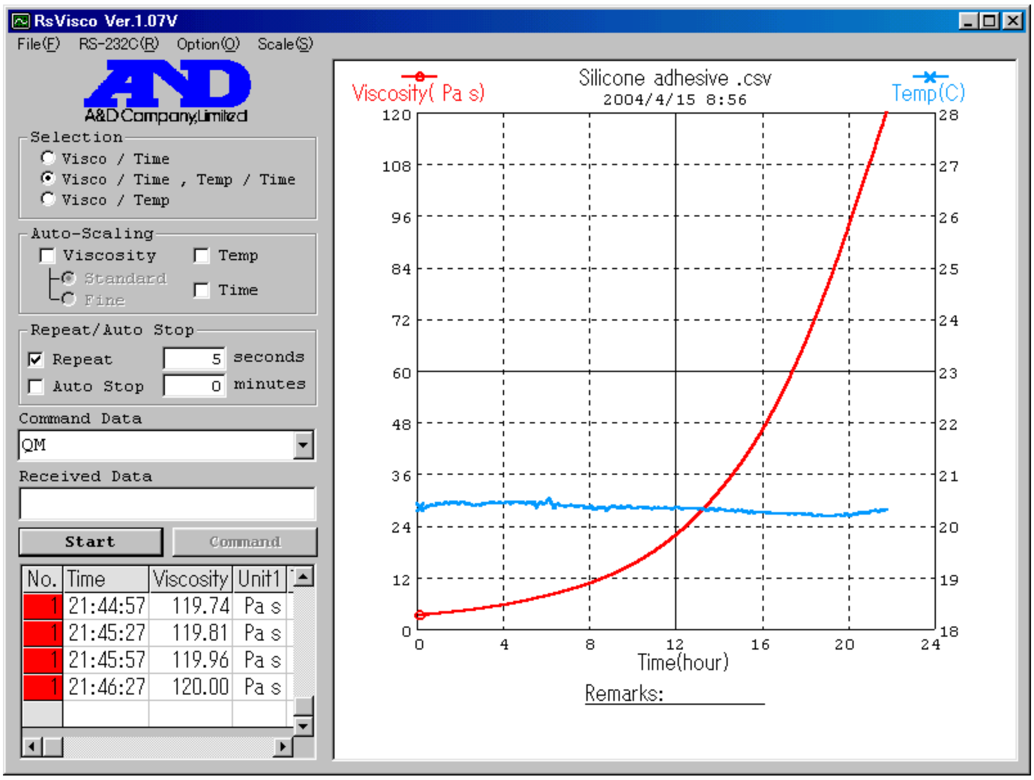


Figure 33 Measurement Example of Curing Process of Silicone Adhesive (SV-100)

A nonionic surface-active agent, when its temperature is raised, becomes cloudy at a certain temperature. This temperature is called the cloud point and has conventionally been measured optically. Using the SV-10, the cloud point can be obtained by measuring changes in the viscosity, because an abrupt change in viscosity occurs at the cloud point, due to changes in physical properties.

Figure 34 shows the results of SV-10 measurement of a nonionic surface-active agent (1% concentration) while it was heated. The graph indicates an abrupt change in viscosity at 35.4°C, which is detected as the cloud point. The cloud point of a nonionic surface-active agent, based on the JIS regulations, is 35.9°C. This indicates that the SV-10 can successfully measure the cloud point.

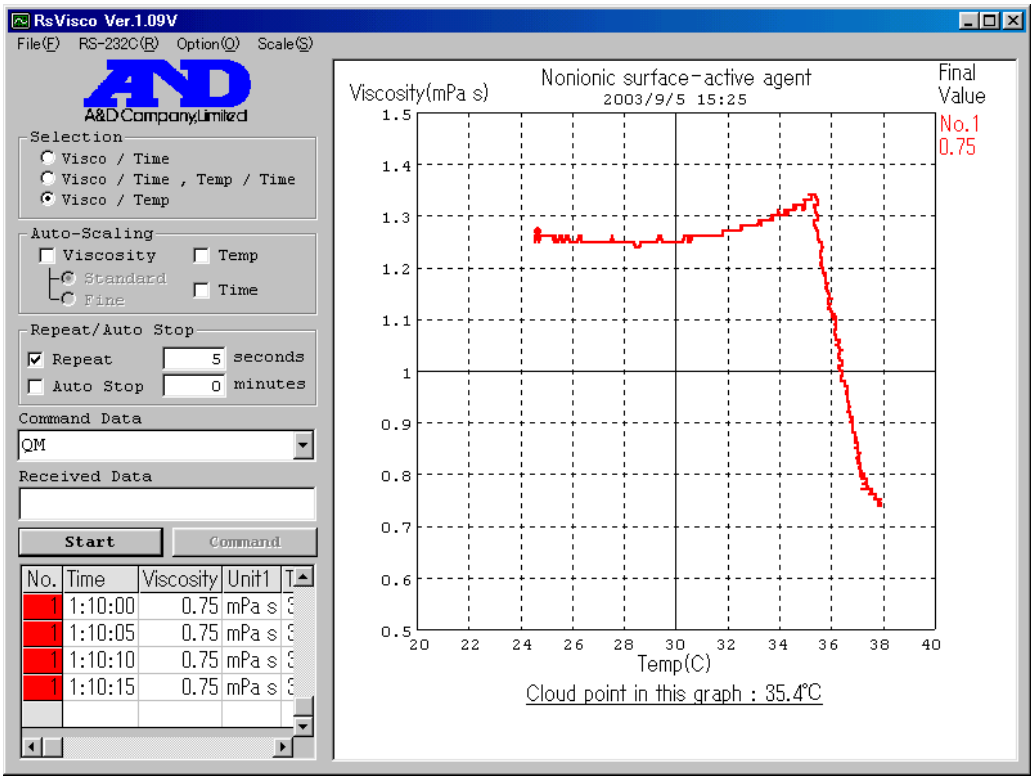


Figure 34 Measurement Example of Nonionic Surface-active Agent (SV-10)

(6) Viscosity Measurement Examples of Fluids of Different Concentrations

Figures 35 and 36 show the SV-10 measurement results of ethanol solutions at different concentrations while keeping the temperature at 25℃. The viscosities vary in response to concentration. When ethanol is 100% and 0% (100% water), the viscosities are low. When mixing them, the viscosity increases.

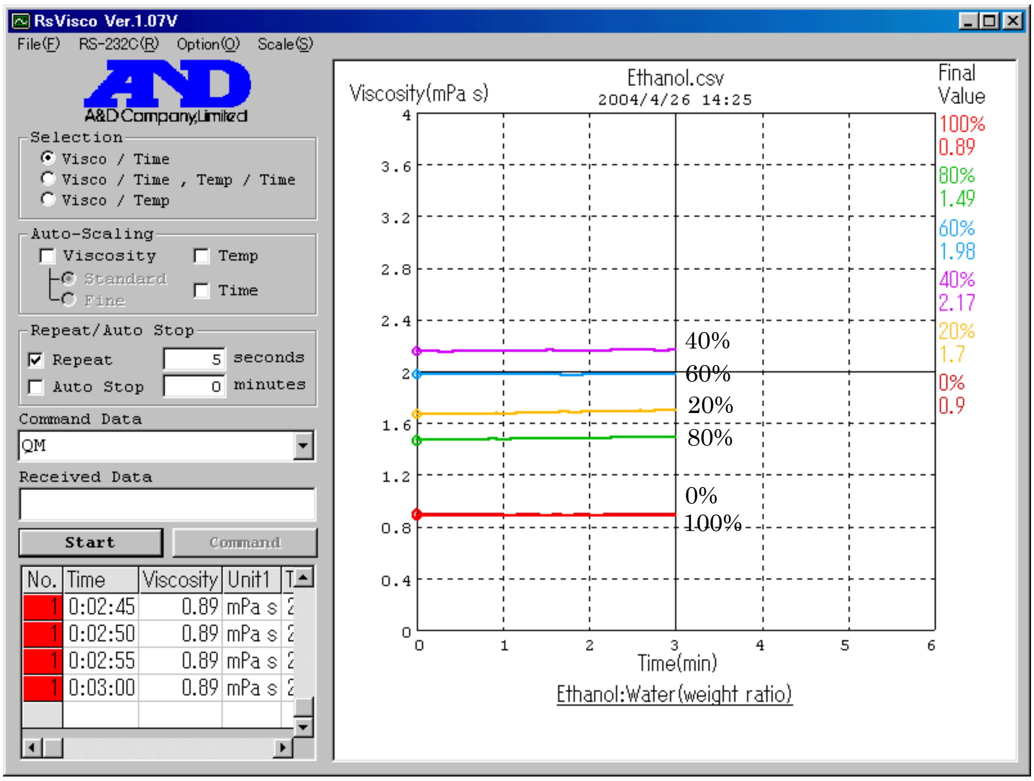
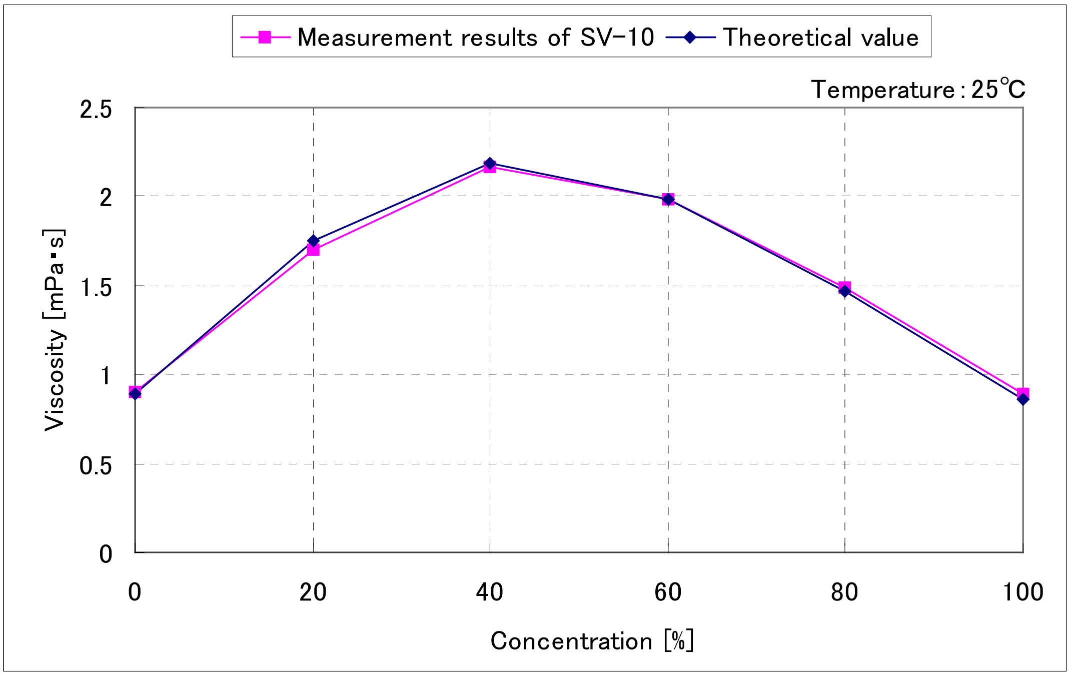


Figure 35 Measurement example of ethanol (SV-10)



"The theoretical value" of viscosity is compensated mathematically with density.

Figure 36 Relation between The Concentration And Viscosity of Ethanol Solution

Figure 37 shows the result of SV-10 measurement of die-cast mold release agent at each concentration diluted with water. It shows that the viscosity varies in response to concentration.
Figure 38 shows the result of SV-10 measurement of insulation coating agent (polyvinyl resin) at each concentration diluted with a fluid. In the high concentration side, the viscosity increases with time. This can be regarded as a status change of sample caused by vaporization. In this way, concentration difference can be also detected by measuring viscosity.

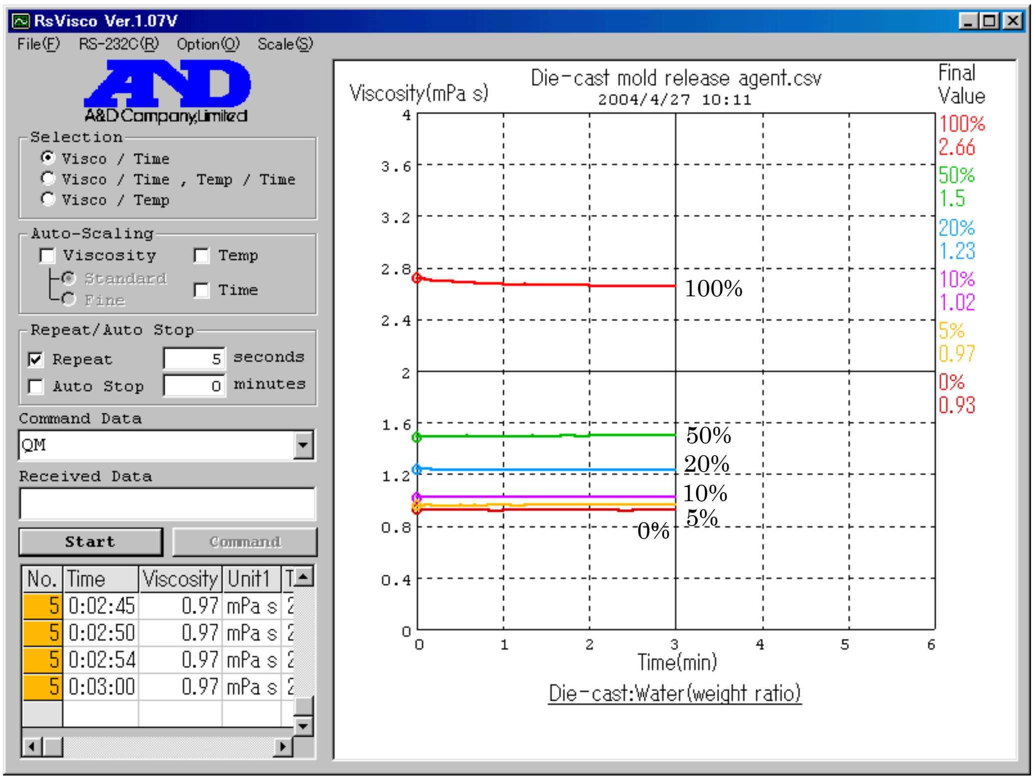


Figure 37 Measurement Example of Die-cast Mold Release Agent (SV-10)

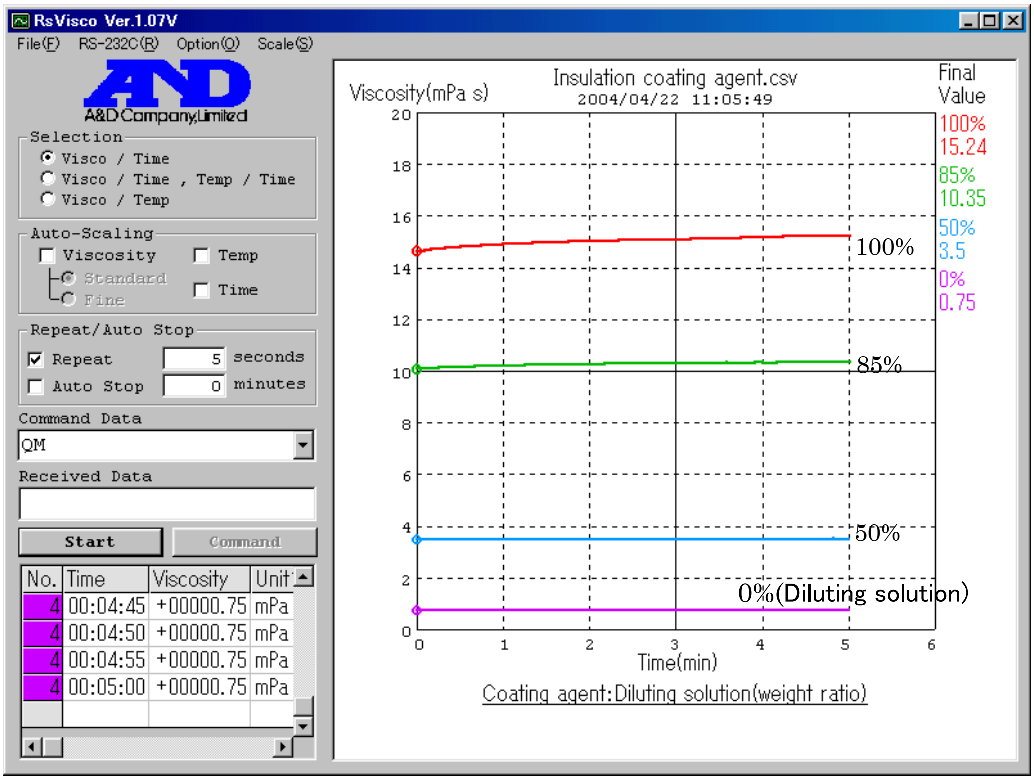


Figure 38 Measurement Example of Insulation Coating Agent (SV-10)

(1) Measuring A Sample at A Constant Temperature

Viscosity (Measured value) : The numerical values on the table are: "Viscosity when the measurement starts to Viscosity when the measurement ends"

The unit of viscosity : mPa·s (Millipascal second)
1 mPa·s = 1 cP (Centipoise), 1 Pa·s (Pascal second) = 10 P (Poise)

Temperature of the sample (Sample temp.) : Averaged sample temperature during measurement

When the SV-10 is used:

No.	Class	Sample Name	Viscosity (Measured value) [mPa·s]	Sample Temp. [°C]	Comments
1	Chemical product	Water (Purified water)	0.92	23.6	No significant change over time.
2	Chemical product	Methyl alcohol	0.42	24.5	No significant change over time.
3	Chemical product	Ethyl alcohol	0.91	24.5	No significant change over time.
4	Household product	Starch glue	6320	25.2	No significant change over time.
5	Household product	Laundry starch	370 to 346	23.3	Decreases with time and then stabilizes. Time to stabilization: 30 minutes
6	Household product	Kitchen detergent	164	23.7	No significant change over time.
7	Household product	Contact lens cleaning solution	5.57	23.3	No significant change over time.
8	Household product	Shampoo with conditioner	705 to 677	25.1	Decreases with time and then stabilizes. Time to stabilization: 6 minutes
9	Household product	Floor wax	4.91	23.6	No significant change over time.
10	Cosmetics product	Skin lotion	1.18	23.6	No significant change over time.
11	Cosmetics product	Skin milk	43.6	23.4	No significant change over time.
12	Cosmetics product	Skin-care cream	1410	24.2	No significant change over time.
13	Cosmetics product	Nail polish	437 to 448	21.6	Increases with time and then stabilizes. Time to stabilization: 1 minute
14	Food product	Cold beverage (Jellylike)	106 to 116	23.0	Increases with time and then stabilizes. Time to stabilization: 12 minutes

No.	Class	Sample Name	Viscosity (Measured value) [mPa·s]	Sample Temp. [°C]	Comments
15	Food product	Tomato juice	18.7 to 21.0	22.7	Increases with time.
16	Food product	Chocolate syrup	987 to 1150	23.7	Increases with time.
17	Food product	Milk	2.27	20.7	No significant change over time.
18	Food product	Milk substitute	85.0 to 83.7	23.0	Decreases with time and then stabilizes. Time to stabilization: 6 minutes
19	Food product	Condensed milk	1540 to 1470	23.3	Decreases with time and then stabilizes. Time to stabilization: 9 minutes
20	Food product	Mustard	428 to 679	23.3	Increases with time.
21	Food product	Ketchup	1660 to 2030	23.3	Increases with time.
22	Food product	Mayonnaise	2570 to 3030	23.7	Increases with time.
23	Food product	Soy sauce	4.76	23.5	No significant change over time.
24	Food product	Worcester sauce	167	23.2	No significant change over time.
25	Food product	Salad oil	54.5	24.2	No significant change over time.
26	Coating material	Synthetic-resin coating (Water-based varnish)	188	22.7	No significant change over time.
27	Coating material	Synthetic-resin coating (Water-based, black)	1300 to 1090	23.3	Decreases with time and then stabilizes. Time to stabilization: 30 minutes
28	Coating material	Synthetic-resin coating (Water-based, transparent)	70.1 to 59.1	23.2	Decreases with time.
29	Coating material	Black ink	16.6 to 15.8	23.3	Decreases with time and then stabilizes. Time to stabilization: 5 minutes
30	Coating material	Black ink (Water dilution at 10% concentration)	1.14	23.2	No significant change over time.
31	Coating material	Red ink	184 to 161	23.2	Decreases with time and then stabilizes. Time to stabilization: 20 minutes

No.	Class	Sample Name	Viscosity (Measured value) [mPa·s]	Sample Temp. [°C]	Comments
33	Other	Alginate impression material	899 to 12000	21.2	Gelates in about 5 minutes after mixed with water.
34	Other	Plaster	11.6 to 12000	24.0	The curing time depends on the mixture ratio with water. (Firure 31)
35	Other	Semiconductor polishing solution A	3.57	24.0	No significant change over time.
36	Other	Semiconductor polishing solution B	1.69	24.0	No significant change over time.
37	Other	Semiconductor polishing solution C	1.06	24.0	No significant change over time.

When the SV-100 is used:

No.	Class	Sample Name	Viscosity (Measured value) [Pa·s]	Sample Temp. [°C]	Comments
38	Coating material	Oil-based ink	17.6 to 17.4	20.1	No significant change over time.
39	Industrial product	Silicone adhesive A (Mixed with B for use)	4.33 to 6.65	24.2	Increases with time and then stabilizes. Time to stabilization: 15 minutes
40	Industrial product	Silicone adhesive B (Mixed with A for use)	2.1	23.6	No significant change over time.
41	Industrial product	Silicone adhesive (Mixed A with B)	3.31 to 120	20.3	Measured while keeping the temperature at 20°C. Cures in about a day.

(2) Measuring The Temperature Coefficient

Measurement method : Viscosity was measured when the sample was heated to about 50°C, and then left to cool.

Viscosity (Measured value) : The numerical values on the table are:
"Viscosity when the measurement starts to Viscosity when the measurement ends"

Temperature of the sample : The numerical values on the table are:
"Temperature when the measurement starts to Temperature when the measurement ends"

Temperature coefficient: Temperature coefficient is calculated by the equation below:
Temperature coefficient

$$= \frac{\text{Viscosity at end - Viscosity at start}}{\text{Temperature at end - Temperature at start}} \times \frac{1}{\text{Averaged viscosity}} \times 100 \ (\%/°C)$$

When the SV-10 is used:

No.	Class	Sample Name	Viscosity (Measured value) [mPa·s]	Sample Temperature [°C]	Temperature Coefficient [%/°C]
42	Chemical product	Water (Purified water)	0.64 to 0.90	40.9 to 24.2	-2.0
43	Household product	Laundry starch	157 to 324	47.3 to 23.3	-2.9
44	Cosmetics product	Foundation	61.2 to 189	48.3 to 26.1	-4.6
45	Food product	Chocolate syrup	660 to 2200	49.4 to 24.5	-4.3
46	Food product	Syrup	50.9 to 205	45.1 to 24.5	-5.8
47	Food product	Mustard	631 to 2100	46.7 to 23.3	-4.6
48	Food product	Worcester sauce	107 to 159	46.9 to 27.0	-2.0
49	Food product	Salad oil	20.5 to 50.8	48.8 to 24.3	-3.5
50	Food product	Honey	508 to 3750	48.0 to 26.4	-7.0
51	Food product	Tea	0.47 to 0.72	56.2 to 38.0	-2.3
52	Food product	Agar	2570 to 12000	72.9 to 48.6	-5.3
53	Industrial product	Silicone oil	643 to 919	45.6 to 26.4	-1.8

When the SV-100 is used:

No.	Class	Sample Name	Viscosity (Measured value) [Pa·s]	Sample Temperature [°C]	Temperature Coefficient [%/°C]
54	Household product	Tooth paste	5.15 to 9.14	63.9 to 24.9	-1.4
55	Household product	Hand cream	2.55 to 28.5	46.0 to 22.9	-14.5
56	Food product	Honey	6.85 to 59.8	21.7 to 7.1	-10.9
57	Food product	Bean jam	22.5 to 48.9	50.0 to 22.2	-3.2
58	Food product	Laver boiled down in soy sauce	27.2 to 31.8	50.5 to 24.2	-0.6

(3) Measuring The Coagulation Point and Cloud Point

When the SV-10 is used:

No.	Sample Name	Measurement method	Comments
59	Egg white	Heated with a heater.	Sets at about 60°C. (Figure 39)
60	Lard	Heated to about 70°C, then left to cool.	Sets at about 26°C. (Figure 40)
61	Dark chocolate	Heated to about 50°C, then left to cool.	Sets at about 25°C. (Figure 41)
62	Milk chocolate	Heated to about 50°C, then left to cool.	Sets at about 25°C. (Figure 41)
63	Gelatin (5% concentration)	Cooled with a temperature controller.	Gelates at about 20°C. (Figure 42)
64	Gelatin (2.5% concentration)	Cooled with a temperature controller.	Gelates at about 12°C. (Figure 42)
65	Lipstick	Heated to about 80°C, then left to cool.	Sets at about 65°C. (Figure 43)
66	Candle	Heated to about 110°C, then left to cool.	Sets at about 60°C. (Figure 44)
67	Solder flux	Heated to about 130°C, then left to cool.	Sets at about 70°C. (Figure 45)
68	Grease A	Heated to about 150°C, then left to cool.	Sets at about 100°C. (Figure 46)
69	Grease B	Heated to about 150°C, then left to cool.	Sets at about 90°C. (Figure 46)
70	Gasoline engine oil	Heated to about 110°C, then left to cool.	Viscosity at 40°C: 7.64 mPa·s Viscosity at 100°C: 45.4 mPa·s (Figure 47)
71	Diesel engine oil	Heated to about 110°C, then left to cool.	Viscosity at 40°C: 9.01 mPa·s Viscosity at 100°C: 77.1 mPa·s (Figure 48)
72	Nonionic surface-active agent (1% concentration)	Heated with a temperature controller.	Cloud point based on the JIS* regulations: 35.9°C. Measurement result with the SV-10: 35.4°C. (Figure 49)

* JIS = Japanese Industrial Standards

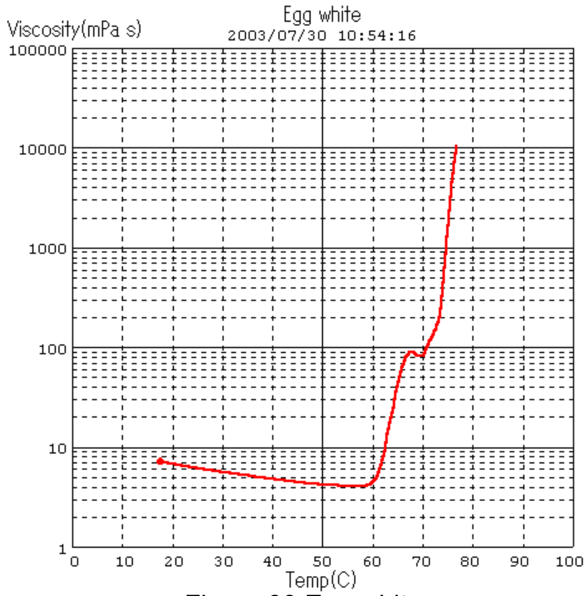


Figure 39 Egg white

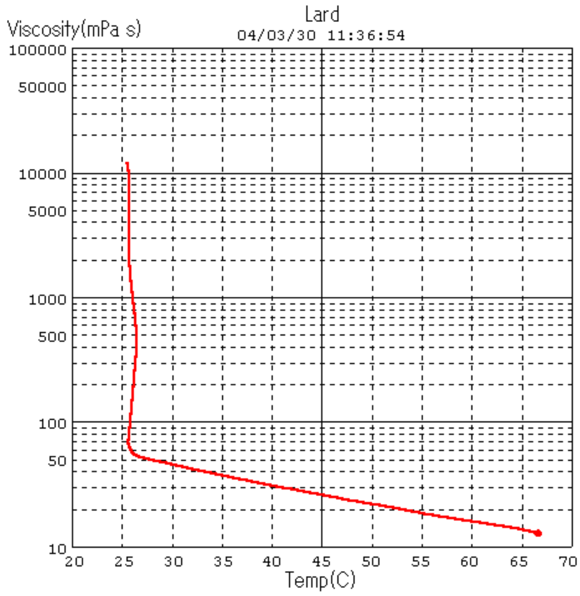


Figure 40 Lard

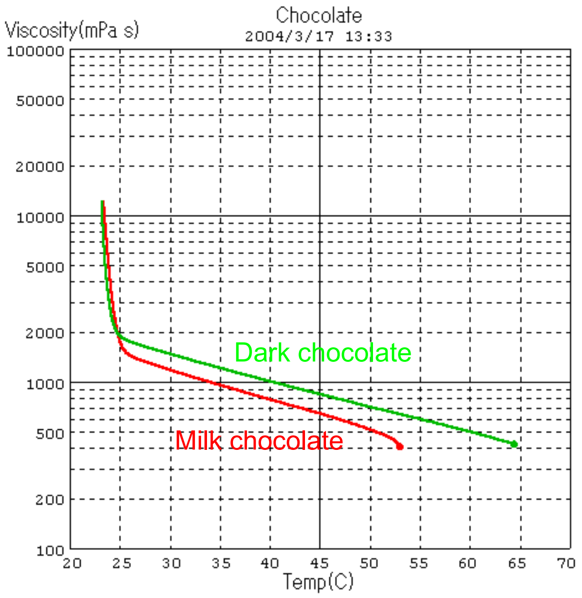


Figure 41 Chocolate

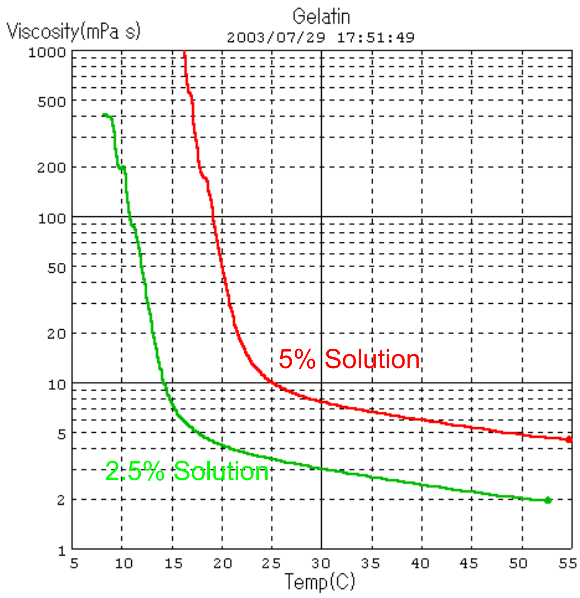


Figure 42 Gelatin

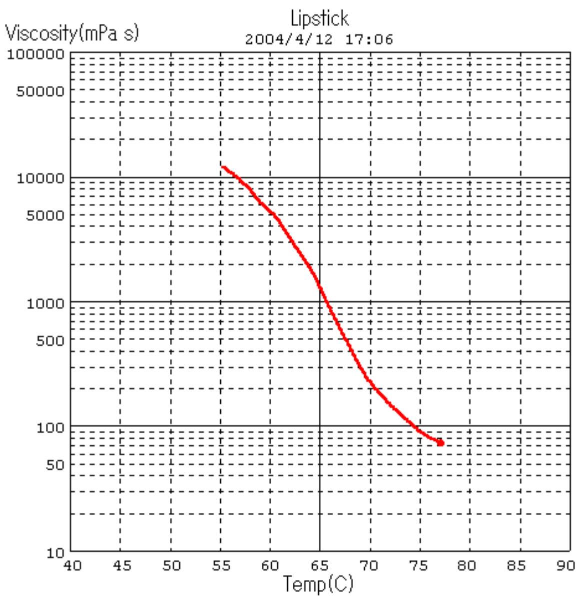


Figure 43 Lipstick

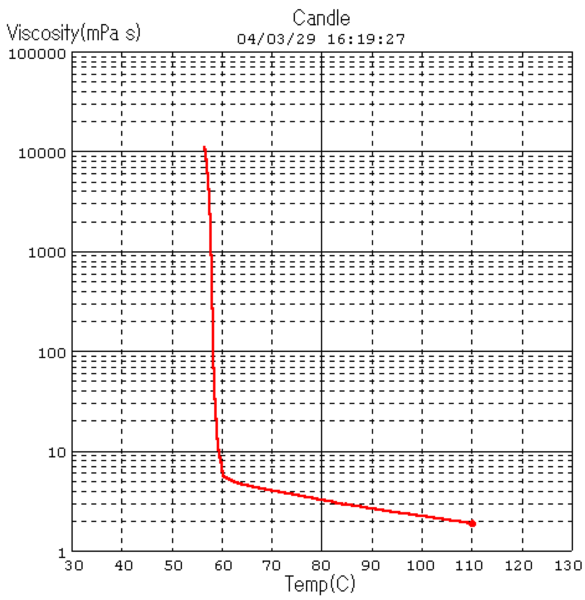


Figure 44 Candle

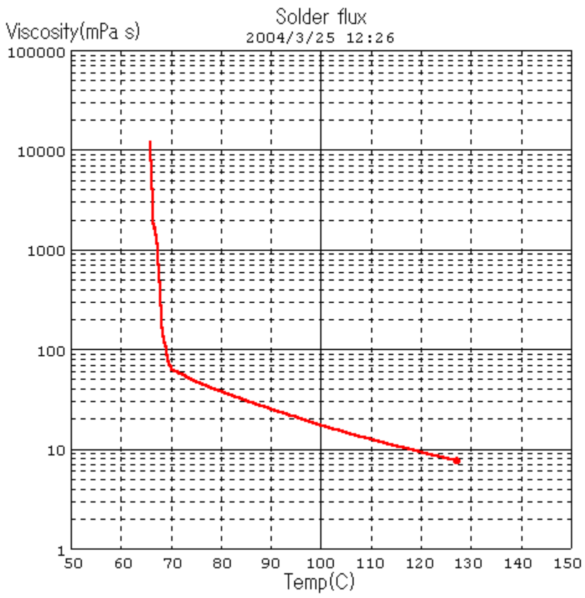


Figure 45 Solder flux

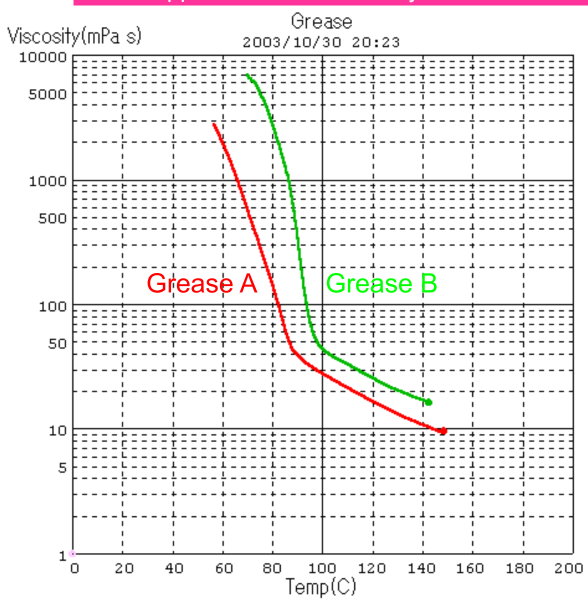


Figure 46 Grease

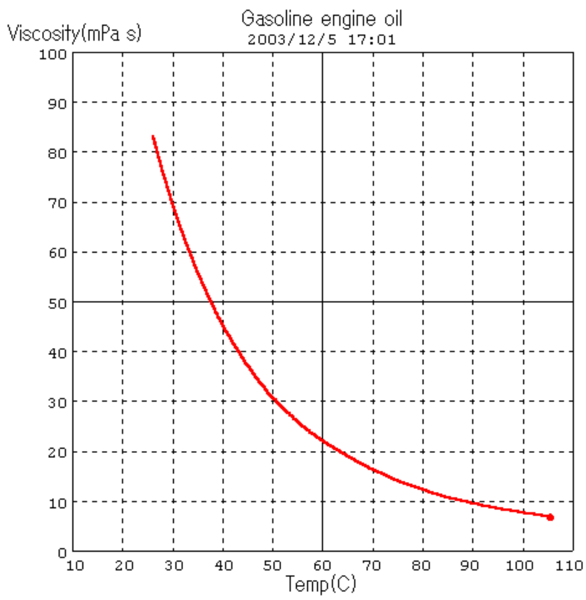


Figure 47 Gasoline engine oil

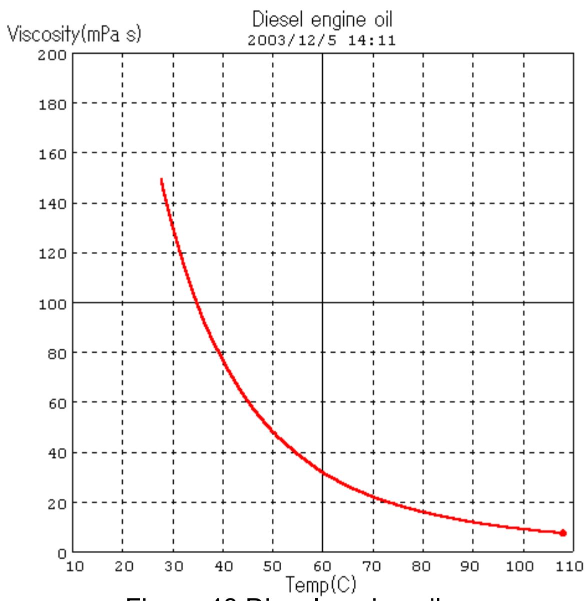


Figure 48 Diesel engine oil

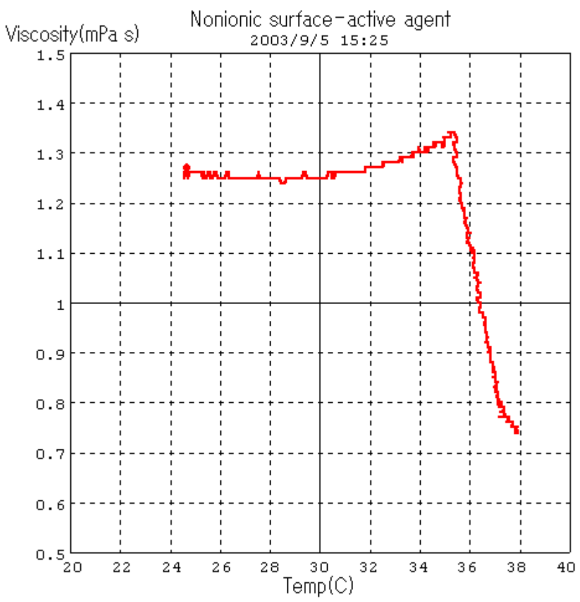


Figure 49 Nonionic surface-active agent

(4). Measuring A Sample While Changing Its Concentration

(a) Ethanol solution

Measurement method : The viscosity of an ethanol solution, which was diluted with purified water, was measured with regard to each concentration (weight ratio).

Temperature of the sample : 25.0°C

When the SV-10 is used: (Figure 35,36)

No.	Sample Name	Viscosity (Measured value) [mPa·s]
73	Ethanol solution (100% concentration)	0.89
74	Ethanol solution (80% concentration)	1.49
75	Ethanol solution (60% concentration)	1.98
76	Ethanol solution (40% concentration)	2.17
77	Ethanol solution (20concentration)	1.70
78	Purified water (0% concentration)	0.90

(b) Die-cast mold release agent

Measurement method : The viscosity of a die-cast mold release agent, which was diluted with purified water, was measured with regard to each concentration (weight ratio).

Temperature of the sample : 23.5°C

When the SV-10 is used: (Figure 37)

No.	Sample Name	Viscosity (Measured value) [mPa·s]
79	Die-cast mold release agent (Undiluted)	2.66
80	Die-cast mold release agent (Water dilution at 50% concentration)	1.50
81	Die-cast mold release agent (Water dilution at 20% concentration)	1.23
82	Die-cast mold release agent (Water dilution at 10% concentration)	1.02
83	Die-cast mold release agent (Water dilution at 5% concentration)	0.97
84	Purified water	0.93

(c) Insulation coating agent

Measurement method : The viscosity of an insulation coating agent, which was diluted with diluting solution, was measured with regard to each concentration (weight ratio).

Temperature of the sample : 22.5°C

When the SV-10 is used: (Figure 38)

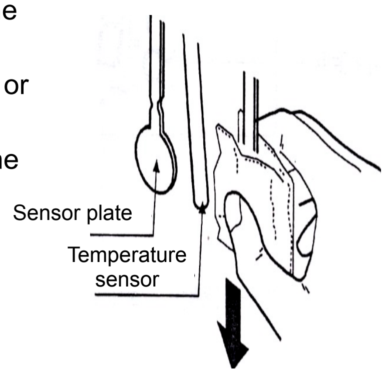
No.	Sample Name	Viscosity (Measured value) [mPa·s]
85	Insulation coating agent (100% concentration)	14.7
86	Insulation coating agent (85% concentration)	10.0
87	Insulation coating agent (50% concentration)	3.49
88	Diluting solution	0.75

■Maintenance

A. Sensor Plate

No.	Question	Answer
34	Can a user exchange the sensor plates?	If one of the sensor plates is damaged or you cannot get rid of some residue from a congealed sample, please send us the measurement unit together with the display unit for exchanging and adjustment.

B. Cleaning

No.	Question	Answer
35	How should I clean the measurement unit?	After measurement, please clean the sensor plates, temperature sensor, and protector with a cleaning agent or solvent to remove sample residue. Clean it as soon as possible after the measurement, especially if it is a curing sample. Clean the sample cup as well. If the cleaning agent is not volatile, wipe it off with purified water, so as not to affect the next sample measurement.  How to clean: As shown in the figure above, hold the sensor plate or temperature sensor lightly with a tissue between your fingers and wipe off any sample residue with the tissue by sliding it from top to bottom. Please note that if you slide it from the bottom to the top the sensor plate may become buckled and/or damaged. After that, soak a tissue with a cleaning agent or solvent and then clean in the same way using this tissue. Clean with purified water if necessary. Normally, the sensor plates, temperature sensor, or protector will not be damaged if pressed lightly between your fingers. However, we strongly advise that you do not apply any unnatural or unnecessary force or pressure to them.

C. Troubleshooting

No.	Question	Answer
36	When measurement values are not stable.	Is the ambient environment free from vibration and/or drafts? ●Use a solid operation table. ●Avoid direct drafts in the vicinity of the viscometer. ●Reconsider the setting of "Condition" of the function setting. Is there a strong electrical or magnetic noise source such as a motor near the viscometer? Is the protector or sensor protective cover in contact with the sensor plates or the temperature sensor? ●Attach the protector and the sensor protective cover properly so that they do not touch the sensor plates or temperature sensor. ●Remove the protector or the sensor protective cover when necessary.
37	When measurement values are not stable.	Has the sample surface been adjusted to the center of the narrow part of the sensor plates? ●Adjust the table height by turning the knob so that the center of the narrow part of the sensor plates is on the sample. Are the positions of the left and right sensor plates in the sample surface level? ●If not the same, level the viscometer using the leveling feet so that the liquid surface is level. The gradients in the front and back do not have much measuring sensitivity because the sensor plates are only 0.3mm thick. Are the sensor plates bent? ●If bent, contact your local A&D dealer for repair. Is the sample generating bubbles because of the differences in the sample temperature and the ambient temperature and are these bubbles sticking to the sensor plates? Has calibration been performed? ●When the absolute viscosity value is important, it is recommended that periodic calibration be performed using a standard viscosity fluid.
38	When the temperature values are incorrect.	Is the display unit connected to the main unit properly with the connection cable? Since the measurement unit and display unit are adjusted as a pair, you should not perform adjustment of units with different serial numbers.
39	Is only the left sensor plate vibrating vigorously?	This sometimes occurs when only the left sensor plate sets in a sample during a curing process measurement. In such a case, agitate the sample well to make the sample state the same quality on both the right and left side of the sensor plates.

§ Specifications of the Sine-wave Vibro Viscometer SV series

Measurement Method: Sine-wave Vibro Viscometer using the Tuning-fork Vibration Method
Vibration frequency 30 Hz

Viscosity Measurement Range: SV-10 : 0.3 to 10000mPa•s (cP) / SV-100 : 1 to 100 Pa•s (10 to 1000 P)

Viscosity Measurement Repeatability: 1% (Standard deviation)

Minimum Display

	SV-10		SV-100
Viscosity Range (mPa•s)	Minimum Display (mPa•s)	Minimum Display (mPa•s)	Minimum Display (mPa•s)
0.3 to 10	0.01	0.0001	—
10 to 100	0.1	0.0001	—
100 to 1000	1	0.001	—
1000 to 10000	10*	0.01	0.01
10000 to 100000	—	—	0.1

*Here, the unit changes to Pa•s.

Units (Viscosity): mPa•s*, Pa•s, cP*, P *Only SV-10

Operating temperature: 10 to 40°C
50 to 104°F

Minimum sample amount: 35ml or more

Sample Temperature Measurement Unit: 0 to 160°C /0.1°C
32 to 320°F /0.1°F

Temperature Measurement Error Limit:

±1°C (0 to 20°C)	±1.8°F (32 to 68°F)
±0.5°C (20 to 30°C)	±0.9°F (68 to 86°F)
±2°C (30 to 100°C)	±3.6°F (86 to 212°F)
±5°C (100 to 160°C)	±7.2°F (212 to 320°F)

Display: Vacuum fluorescent display (VFD)

Connection cable Length: 1.5m (between the main unit and display unit)

Communication: RS-232C standard

Power Supply: AC adapter (Confirm that the adapter type is correct for the local voltage and power receptacle type.)

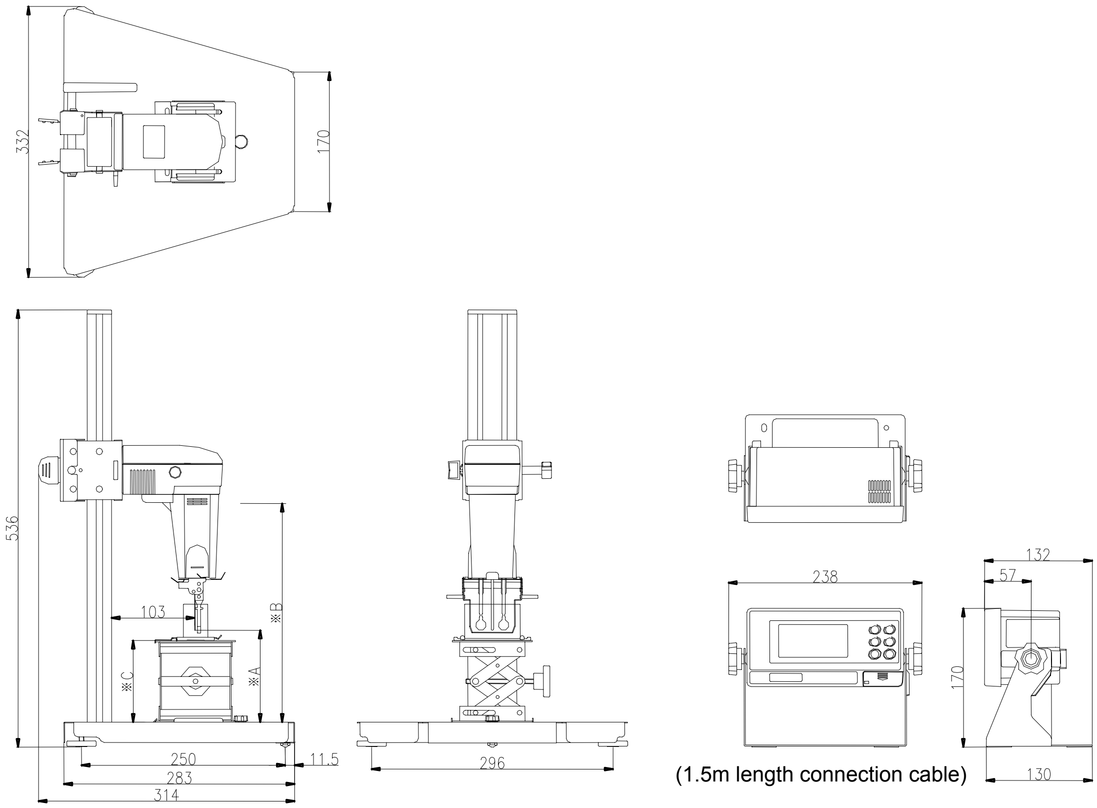
Power consumption: Approx. 14VA (Including the AC adapter)

External dimension/mass:
Main unit 332 (W) × 314 (D) × 536 (H) mm/Approx. 5.0 kg
Display unit 238 (W) × 132 (D) × 170 (H) mm/Approx. 1.3 kg

Standard Accessories:
AC adapter (1 pc.)
Windows communication tools for Viscosity (WinCT-Viscosity) CD-ROM (1 pc.)
sample cups (4 pc.)
RS-232C cable (25P-9P, 1 pc.)
Connection cable (1.5m, 1 pc.)

Option:
AX-SV-33 Sample cup (PC [polycarbonate], 35-45ml) Same as container that with SV unit. Set of 10
AX-SV-34 Small sample cup (PC[polycarbonate],10ml) Set of 10
AX-SV-35 Glass sample cup (volume approx. 13ml)
AX-SV-36 Positioning stopper
AX-SV-37 Water jacket (body:polycarbonate, packing:silicon gum), with 4 set small sample cup and lids
AX-SV-38 Glass sample cup (volume approx. 60ml) Set of 10
AX-SV-39 Plastic sample cup (volume approx. 120ml) Set of 20
AX-SV-43 Extension cable (5m) to connect measuring unit to display unit
AD-8121B Compact printer

Dimensions



*A=Lowest level of the sensor plates 3.5mm (protector in use, table excluded)

*B=Highest level of the sensor plates 268mm

*C=Level of table (54 – 140mm)

Units: mm