# SV-A Series

## Sine-wave Vibro Viscometer

# Users' Handbook


Version 1.13E

June 2009

International Div., A&D Company, Limited

## Viscometry Revolution!

A&D Company, Limited ...Clearly a Better Value
http://www.aandd.jp

# Contents

## Basis



## Product (Sine-wave Vibro Viscometer SV-A Series)

## ■Application



## ■Maintenance

## ■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 petrochemical 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:

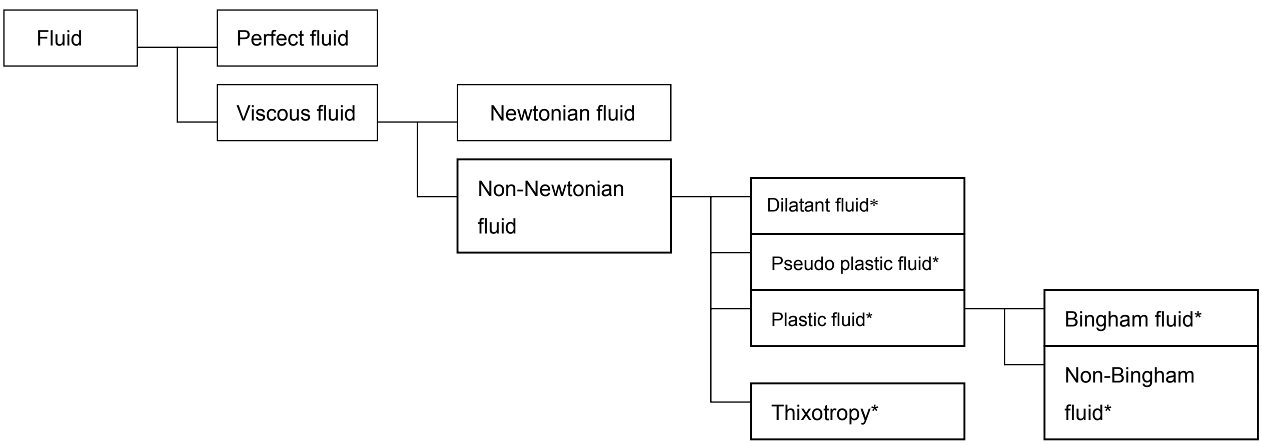
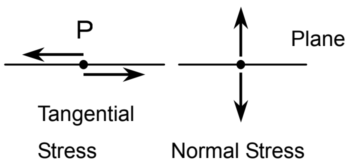



Figure 1 Physical Classification of Fluid

* 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,

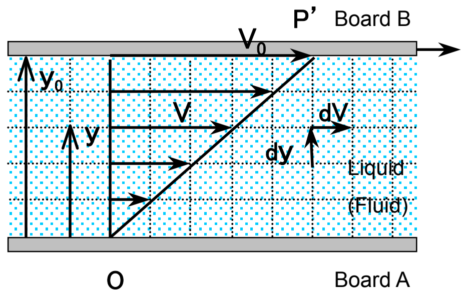



Figure 2 Couette Flow (Newtonian Fluid)

**D = V/y**

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

**D = dV/dy** (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 $\tau$ stands for a tangential stress, it is proportionate to shear stress D. Where $\eta$ stands for the proportional constant,

$\tau = \eta D$ (Newton's law of viscosity) (2)

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

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

The fluid subject to this law, whose viscosity $\eta$ at specific temperature is constant in spite of shear rate D or shear stress $\tau$, is called a **Newtonian fluid**. If shear rate D and shear stress $\tau$ are not proportionate, i.e. if viscosity $\eta$ of the fluid is variable with the quantities of shear rate D or shear stress $\tau$, 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 $\tau$. As straight line ① shows, where they are in proportion indicating a constant slope of the line, it is a Newtonian fluid. Where $\theta$ stands for the slope, viscosity $\eta$ is represented by the following equation (4);

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

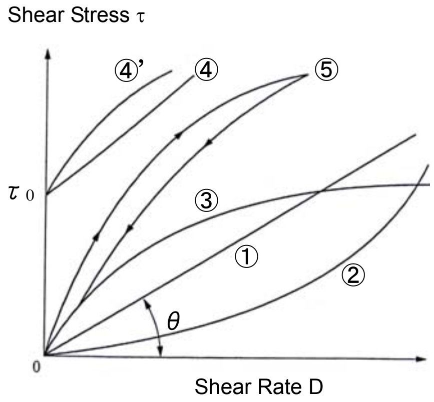



Figure 3 Newtonian Fluid and Non-Newtonian Fluid (Yutaka Matsuyama, Jitsuyo Kogyo Bunseki, 61, The Energy Conservation Center, 2001)

The fluids with fluidities such as indicated by lines ② - ⑤ are non-Newtonian fluids. Viscosity $\tau$/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 $\tau_0$ (yield stress) of specific criticality after increased from zero. After reaching the yield stress, if the relationship between $\tau$ 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 $\tau$ is force per unit area. The unit of force is Newton (N). Therefore the unit of $\tau$ 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 $\eta$ is [Pa]/ [$s^{-1}$]=[Pa·s]. [Pa·s] reads "Pascal·second".

(SI unit system) **Unit of viscosity $\eta$ 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 $\tau$ is [dyne/$cm^2$]. Since the unit of shear rate D is [$s^{-1}$] above, the unit of viscosity $\eta$ is represented by [dyne/$cm^2$]/ [$s^{-1}$]= [dyne·s/$cm^2$], which is called poise [P].

(CGS unit system) **Unit of viscosity $\eta$ is [P]** (6)

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

**1[m Pa•s]=1[cP]** (7)

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

The result given by dividing viscosity $\eta$ by density $\rho$ of the liquid is called **kinematic viscosity**, or **kinetic viscosity**, or **dynamic viscosity**.
Where a symbol $\nu$ 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): **$1\times10^{-4}$[$m^2$/s]=1[$cm^2$/s]=1[St]** (11)
Or; **$1\times10^{-6}$[$m^2$/s]=1[$mm^2$/s]=$1\times10^{-2}$[St]=1[cSt]** (12)

[cSt] reads as "centi-stokes".

**Reference – Viscosity**

As shown in Figure 4, where stress $\tau$ 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 $\eta$ of this liquid is given as 1 poise [P], or according to the equation (7), as 0.1 Pascal second [Pa•s].

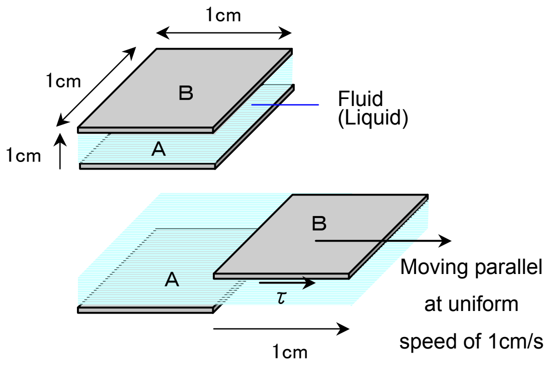



Figure 4 Geometric Definition of Viscosity

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.

The driving force required for the viscidity is directly proportional to the viscosity × density. Therefore, when vibrating the spring plates with a constant frequency to develop uniform amplitude for samples with differing viscosities, the driving electric current (driving power) is also directly proportional to the product of viscosity and density of each sample.

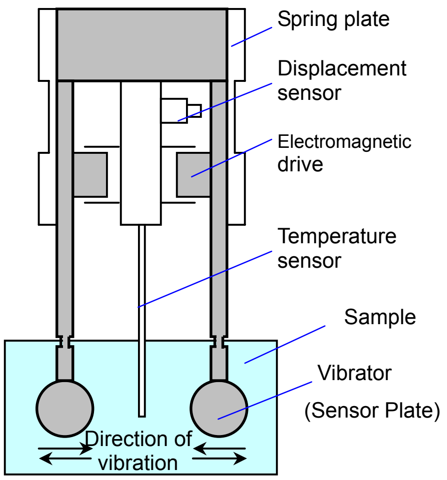


Figure 5 Vibro Viscometer (Detection System)

Using a theoretical formula based on this measurement principle, the physical quantity measured by vibro viscometers is detected as "viscosity × density." **The same is true for A&D's vibro viscometer SV-A Series**, which displays a value of viscosity × density. While "mPa•s" is used as the unit of measurement for the displayed value of the SV-A Series, if the density of the sample is not 1 [kg/m$^3$], it is possible to obtain the absolute viscosity value by dividing the displayed value by the density of the sample.

A&D's vibro viscometer SV-A 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-A Series can determine a wide dynamic range of viscosity measurement. The ranges for the SV-1A, SV-10A and SV-100A are 0.3 mPa•s to 1,000 mPa•s, 0.3 mPa•s to 10,000 mPa•s, and 1 Pa•s to 100 Pa•s, respectively. The SV-A Series 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.

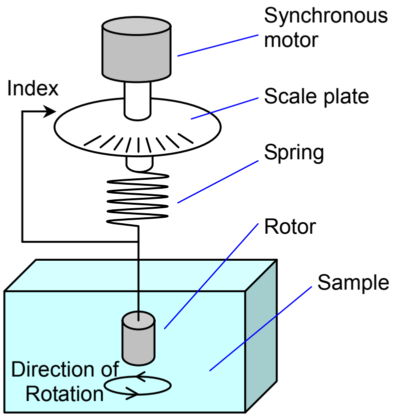


Figure 6 Principle of Rotational Viscometer

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

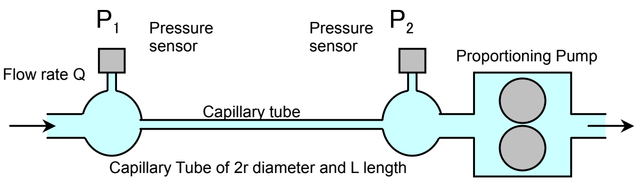



Figure 7 Principle of Capillary Viscometer

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 ΔP/L. This phenomenon is called **Poiseuille's law** and represented by the equation (13).

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

From equation (13), viscosity $\eta$ 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 $\eta$ 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 $\nu$ 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;

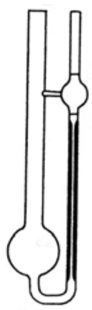



Figure 8 Capillary Viscometer (Free-fall)

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

The correlation between kinetic viscosity and viscosity is represented by equation (8) above, so viscosity $\eta$ is represented by equation (16) measuring density $\rho$ 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.

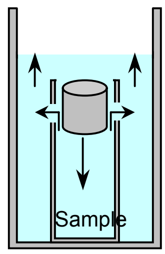



Figure 9 Principle of Falling-ball Viscometer

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.

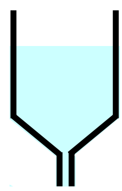


Figure 10 Cup-type Viscometer

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.

## 3. Viscosity of Water

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. v(mm$^2$/s) | Temp. t (°C) | Visco. η (mPa•s) | Kine. Visco. v(mm$^2$/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

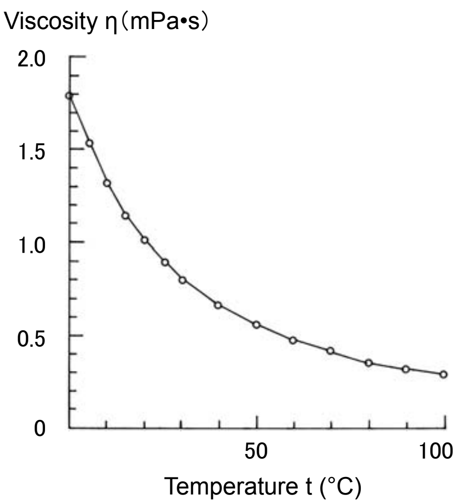



Figure 11 Correlation between Viscosity and Temperature of Water (1 atm)

| No. | Question | Answer |
|---|---|---|
| 1 | Can a user perform viscosity coefficient calibration? | Yes. Users can calibrate the SV-A 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.<br><br>- The Vibro Viscometer SV-A Series requires no replacement of sensor plates over a wide viscosity range. The ranges for the SV-1A, SV-10A and SV-100A are 0.3 mPa•s to 1,000 mPa•s, 0.3 mPa•s to 10,000 mPa•s, and 1 Pa•s to 100 Pa•s, respectively. 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.<br>- 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-A 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.<br>With the SV-1A/10A, simplified calibration using purified water is available when measuring the viscosity near 1mPa•s. This function enables very easy calibration as the temperature compensation is automatically performed based on the temperature of the purified water used. |

| No. | Question | Answer |
|---|---|---|
| 3 | How is viscosity calibration performed? | For both one-point and two-point calibrations, enter the product of the absolute viscosity value and the density of the Viscosity Standard Fluid as the correction value. After calibration, check the values, comparing the product described in the preceding sentence with the displayed value.<br><br>From the equation (8), Density = Viscosity / Kinetic viscosity<br><br>Therefore,<br><br>The displayed value of the SV-A Series, Viscosity × Density = $Viscosity^2$ / Kinetic viscosity<br><br>**Example 1:**<br>**To calibrate the viscometer using a standard viscosity fluid:**<br>Using the calculation sheet, calculate the value used for calibration.<br>(1) Check the kinetic viscosity and the viscosity at the temperature when the calibration is performed.<br><br>In this example, the kinetic viscosity is 1011 $mm^2/s$ and the viscosity is 889 mPa･s at 20 °C.<br><br>(2) Substitute the values above to obtain the value for $Viscosity^2$ / Kinetic viscosity.<br><br>$889^2 / 1011 \fallingdotseq 781$<br>In this example, 781 mPa･s is the correction value used for calibration.<br><br>**Example 2:**<br>**To calibrate using a standard viscosity fluid with known values of viscosity and density.**<br>In this example, a standard viscosity fluid with a viscosity of 889 mPa･s at 20°C is used.<br><br>(1) Check the viscosity value and the density of the standard viscosity fluid at the temperature when the calibration is performed.<br><br>In this example, the viscosity is 889 mPa･s and the density is 0.878 for at 20 °C.<br><br>(2) Substitute the values above to obtain the value for Viscosity × Density.<br><br>$889 \times 0.878 \fallingdotseq 781$<br>In this example, 781 mPa･s is the correction value used for calibration. |

| No. | Question | Answer |
|---|---|---|
| 4 | What is JCSS standardization and how is it related to the SV-A Series? | Vibro viscometers, including the SV-A Series, are accredited as a Japan Calibration Service System (JCSS) standard device for viscosity measurement by the National Institute of Technology and Evaluation (NITE), along with the capillary viscometer and the rotational viscometer.<br>JCSS is a national system of traceability based on The Measurement Act of Japan. |
| 5 | Is a Traceability System Diagram and Certificate available? | Yes. A Traceability System Diagram and Certificate on viscosity and temperature can be issued. The SV-A 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-1A will be inspected with Standard Liquids JS2.5 and JS100, SV-10A with JS2.5 and JS1000, and the SV-100A with JS2000 (or silicone oil) and JS14000.<br>Temperature inspection is given at a fixed temperature around room temperature.<br>Please ask for a Certificate on the placement of your order. (Issuance of Certificate will be charged.)<br>If you need a Certificate for the product after purchase, it is necessary to send the whole SV-A unit to us. |

| No. | Question | Answer |
|---|---|---|
| 6 | What is the measurement accuracy of the viscometer?<br><br>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, repeatability is expressed using the standard deviation.<br>For the SV-A 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. (Please note that the 1% repeatability is obtained when measurements are performed using the 2 ml sample cup for the SV-1A and the 45 ml sample cup for the SV-10A/100A without putting in and taking out the sensor plates.)<br>- Example of 1% standard deviation: When repeating measurement of a liquid of 100mPa·s viscosity, values between 99mPa·s and 101 mPa·s will be indicated 67 times out of 100. |
| 7 | 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-A 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. (Please note that 1% repeatability is obtained when measurements are performed using the 2 ml sample cup for the SV-1A and the 45 ml sample cup for the SV-10A/100A without putting in and taking out the sensor plates.) |

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<br>(1% of measured value) | 0.1 mPa·s | 1 mPa·s | 10 mPa·s |
| Other method<br>(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-A Series

The Sine-wave Vibro Viscometer SV-A 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.
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 SV-A Series displays a viscosity × density value.
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.

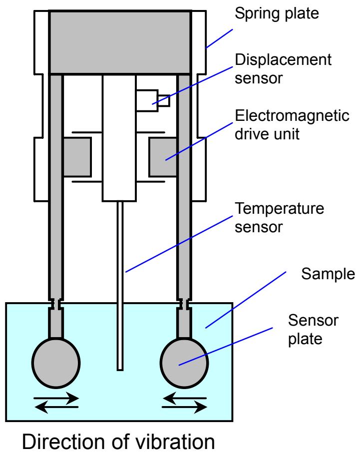



Figure 12 Viscosity Detection Unit (Vibration System)

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

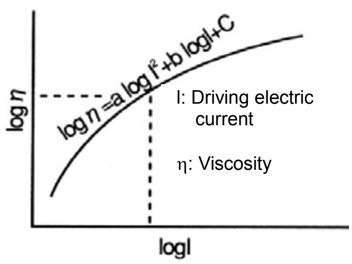



Figure 13 Correlation between Electromagnetic Drive Unit and Driving Electric Current

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 over a wide range of viscosity. The ranges for the SV-1A, SV-10A and SV-100A are 0.3 mPa•s to 1,000 mPa•s, 0.3 mPa•s to 10,000 mPa•s, and 1 Pa•s to 100 Pa•s, respectively. (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-A Series. You can create real time graphs of data regarding viscosity and temperature as shown in Figure 14 with this software.

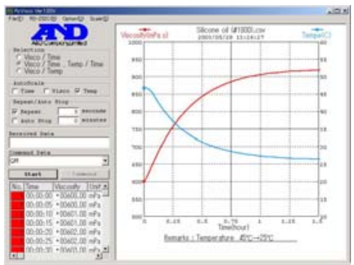


Figure 14 Real Time Display of Measured Data (WinCT-Viscosity)

| No. | Question | Answer |
|---|---|---|
| 8 | How does the SV-A Series operate? | It uses the SV method (the Sine-wave Vibro Viscometer).<br>Please see “Product A. Mechanism and Features of Sine-wave Vibro Viscometer SV-A Series” for more details. |
| 9 | 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.<br>Please see “Product A. Mechanism and Features of Sine-wave Vibro Viscometer SV-A Series” for the details. |
| 10 | 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. |
| 11 | 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.<br>To compare several measurement methods, the repeatability of measured results is the key evaluation criteria. The SV-A Series guarantees a repeatability of measured values of 1% over a wide range. The ranges for the SV-1A, SV-10A and SV-100A are 0.3 mPa•s to 1,000 mPa•s, 0.3 mPa•s to 10,000 mPa•s, and 1 Pa•s to 100 Pa•s, respectively. This is something that a conventional viscometer has never achieved. |

| No. | Question | Answer |
|---|---|---|
| 12 | What magnitude of shear rate does the SV-A 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.<br>The SV-A 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;<br>*The SV-1A, SV-10A and SV-100A vibrate using sine-waves with a frequency of 30 Hz and an amplitude of approx. 0.4 mm (approx. 0.8 mm peak-to-peak), approx. 0.2 mm (approx. 0.4 mm peak-to-peak) and approx. 0.1 mm (approx. 0.2 mm peak-to-peak), respectively. |

| | Viscosity coefficient [mPa•s] | Shear rate (max.) [1/s] | Shear rate (effective value) [1/s] |
|---|---|---|---|
| SV-1A | 1 | 3500 | 2500 |
| | 10 | 520 | 370 |
| | 100 | 150 | 100 |
| | 1000 | 110 | 80 |
| SV-10A | 1 | 590 | 420 |
| | 10 | 130 | 92 |
| | 100 | 42 | 30 |
| | 1000 | 17 | 12 |
| | 10000 | 10 | 7 |
| SV-100A | 1000 | 11.4 | 8.1 |
| | 10000 | 8.6 | 6.1 |
| | 100000 | 7.1 | 5.0 |

## C. Measuring Viscosity

| No. | Question | Answer |
|---|---|---|
| 13 | 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.<br>With the SV-A 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. |

| No. | Question | Answer |
|---|---|---|
| 14 | What amount of sample is necessary for a measurement? | The SV-1A requires 1.8 to 2 ml. The SV-10A/100A requires 35 to 45 ml when using the standard sample cup, 10 ml when using the small sample cup, and 13 ml when using the glass sample cup. (The capacity of the glass sample cup for the SV-1A is approx. 2 ml.) Compared to the rotational viscometer (B type), it can measure with a lesser amount. |
| 15 | What repeatability can it achieve? | 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.<br>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. |
| 16 | Is the measurement unit convertible? | 1. The unit of viscosity coefficient can be switched between mPa·s*/Pa·s and cP*/P. *Only SV-1A/10A<br>2. The unit of temperature can be switched between °C and °F. |
| 17 | What is the minimum display (resolution)? | |

●When the unit mPa·s or Pa·s is selected

| | SV-1A | | SV-10A | | SV-100A |
|---|---|---|---|---|---|
| Viscosity | Min. Unit | | Min. Unit | | Min. Unit |
| (mPa·s) | (mPa·s) | (Pa·s) | (mPa·s) | (Pa·s) | (Pa·s) |
| 0.3-10 | 0.01 | 0.0001 | 0.01 | 0.0001 | – |
| 10-100 | 0.1 | 0.0001 | 0.1 | 0.0001 | – |
| 100-1000 | 1 | 0.001 | 1 | 0.001 | – |
| 1000-10000 | – | – | 10*[1] | 0.01 | 0.01 |
| 10000-100000 | – | – | – | – | 0.1 |

*[1] The unit changes to Pa•s.

●When cP or P is selected

| | SV-1A | | SV-10A | | SV-100A |
|---|---|---|---|---|---|
| Viscosity | Min. Unit | | Min. Unit | | Min. Unit |
| (cP) | (cP) | (P) | (cP) | (P) | (P) |
| 0.3-10 | 0.01 | 0.0001 | 0.01 | 0.0001 | – |
| 10-100 | 0.1 | 0.001 | 0.1 | 0.001 | – |
| 100-1000 | 1 | 0.01 | 1 | 0.01 | – |
| 1000-10000 | - | - | 10*[2] | 0.1 | 0.1 |
| 10000-100000 | – | – | – | – | 1 |

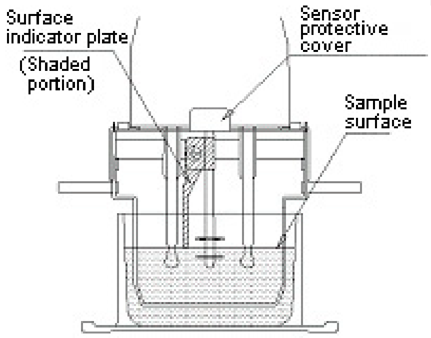
*[2] The unit changes to P.

| No. | Question | Answer |
|---|---|---|
| 18 | Is it necessary to change sensors or parts for each measuring range? | No. The measuring ranges of the SV-A Series are wide: 0.3 mPa•s to 1,000 mPa•s, 0.3 mPa•s to 10,000 mPa•s, and 1 Pa•s to 100 Pa•s for the SV-1A, SV-10A and SV-100A, respectively. Nevertheless, there is no need to exchange sensors over 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.<br>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.<br>Wide range and continuous measurement with the SV-A Series will help develop new materials or functional materials in the research field. |
| 19 | Up to what temperature can a sample be measured? | The measuring range is from 0°C to 160°C.<br>The heat resistance temperature of the accessory sample cup (plastic) is about 120°C, so it is usable for any measurement of a sample at 100°C or lower. |
| 20 | Can the temperature change of a sample be measured simultaneously with viscosity change? | The SV-A 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-A 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.<br>The SV-A 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.<br>The SV-A 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. |
| 21 | Is it possible to measure viscosity at a constant temperature? | Yes. You can measure viscosity at a given temperature by using the provided water jacket 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 |
|---|---|---|
| 22 | 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 provided water jacket and a constant temperature controller (commercially available). It is suited for measurement while adjusting to given temperatures or at a temperature below room temperature.<br>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.<br>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. |
| 23 | What refrigerant should be used for the Water Jacket | 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 and methanol.) |
| 24 | 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 provided glass sample cup 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. |
| 25 | Can I use a different container to the accessory Sample Cups provided? | The SV-A Series has been calibrated for viscosity with the Sample Cups (polycarbonate, volume 2 ml for the SV-1A, 35 ml for the SV-10A/100A). If measuring absolute value of high viscosity over 1000mPa·s, you are strongly recommended to calibrate with the container provided. |
| 26 | What materials are the sensor plates and the temperature sensors, which come in contact with a sample, made of? | They are made of titanium (JIS 2) for the SV-1A/10A/100A.<br>They will not be corroded with a normal organic solvent, and are not easily corroded with an acid or basic (alkaline) solution sample. However, they may be corroded if the acid or basic (alkaline) solution is highly concentrated. |
| 27 | 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 |
|---|---|---|
| 28 | Can I obtain accurate results even from a sample of low viscosity? | 1. Yes. The SV-1A/10A offers you stable measurement results from a sample of low viscosity.<br>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-1A/10A offers, for example, 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.<br>2. In other methods, measuring viscosity in the range of 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-1A/10A can easily measure a sample of low viscosity while tracking the temperature of the sample. |
| 29 | 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-A Series is its ability to continuously measure the viscosity of a flowing sample.<br>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.<br>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 |
|---|---|---|
| 30 | How can I obtain rigorous absolute values of viscosity? | The viscosity coefficient on the SV-A Series' display represents the product of viscosity and density based on measurement principles.<br>In order to obtain the absolute value of viscosity, please divide the measured viscosity value of a sample by its density at that time.<br>Example: where a sample was measured at temperature T, the absolute value will be obtained as follows;<br>1) Viscosity is displayed as 73.6 (mPa･s).<br>2) Density of the sample at temperature T is 0.856.<br>3) The absolute value of viscosity $\eta_M$ is 73.6/0.856=85.98 (mPa•s).<br><br>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 (AD-1653). It can be easily obtained with A&D's analytical electric balance GH/GR Series or precision electronic balance GX/GF Series and Density Determination Kit.<br>*In this case, measure the viscosity under the same temperature condition as the density (specific gravity) was measured. |
| 31 | Is it possible to measure kinetic viscosity? | No. The Vibro Viscometer cannot directly measure it.<br>You can calculate it by obtaining the absolute value $\eta_M$ as in Q&A28 and dividing it once again by the density of a sample. |

| No. | Question | Answer |
|---|---|---|
| 32 | To what level should the surface of a sample fluid reach?<br><br>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 surface indicator plate, the tip of the surface indicator plate 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.<br><br><br>2. For the SV-1A, adjust the sample surface between the upper and lower triangular marks at the center of the narrow part of the sensor plates.<br>3. If the surface of the fluid changes by 1 mm, the SV-1A and the SV-10A will measure a viscosity change of about 10% and 5%, respectively. However, experience indicates that after performing several measurements, you will become able to adjust the sample surface consistently at almost the same level. 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-100A, 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 surface indicator plate.<br>4. 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.<br>5. 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 |
|---|---|---|
| 33 | 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**<br>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.<br>**2. Change of Sample Over Time**<br>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-A 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.<br>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.<br>**3. Separation in a Sample**<br>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 provided water jacket can be attached with the stirrer.)<br>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.<br>**4. Fixed Contamination on the Sensor Plates**<br>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. |

| *No.* | *Question* | *Answer* |
|---|---|---|
| 34 | Is it possible to print out measured results?<br><br>Is it possible to collect and save measured data? | Yes. Output printing and data collection are possible.<br>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.<br>Please use the AD-8121B accessory cable for connection.<br>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.<br>* 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 RS-232C, this software enables A&D's Sine-wave Vibro Viscometer SV-A 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-A 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-A 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.<br>2. The following three types of graphs are provided to choose from;<br>①Viscosity (Y axis) – Time (X axis)<br>②Viscosity/Temperature (Y axis) – Time (X axis)<br>③Viscosity (Y axis) – Temperature (X axis)<br>3. Graphs can be overlaid with different measurements (in 10 colors).<br>4. Measured data can be saved in a CSV format file.<br>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-A Series.<br>1) Recorded data can be saved in a text file.<br>2) Received data can be printed with a printer via a PC.<br>3) Simultaneous communication with multiple viscometers connected to ports of a PC is possible. (Multiprocessing) |
| ●RsKey | 1. Data output from the SV-A Series can be imported to general application software (Microsoft Excel, etc.) via the RS-232C.<br>It is useful to process data using other application software.<br>2. Data output from the SV-A Series can be automatically input to application software as if it were input with a keyboard.<br>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.

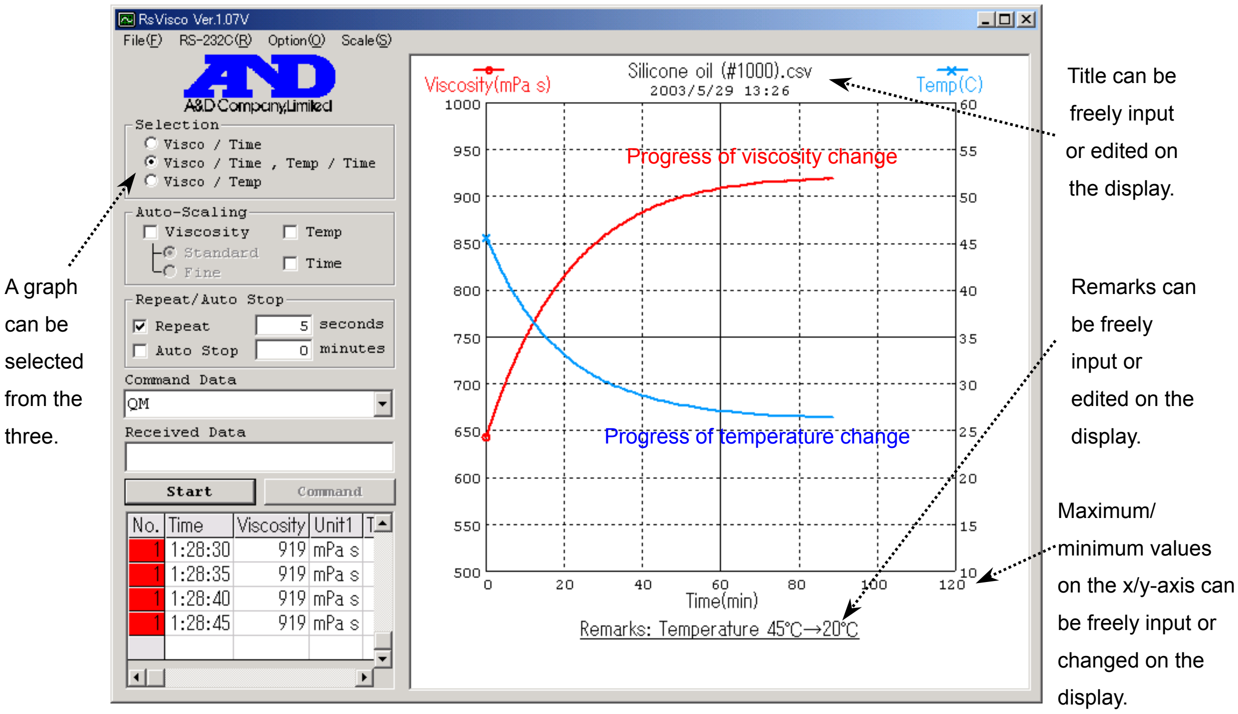



Figure 15 Example of Measurement Display of Silicon Oil (SV-10A)

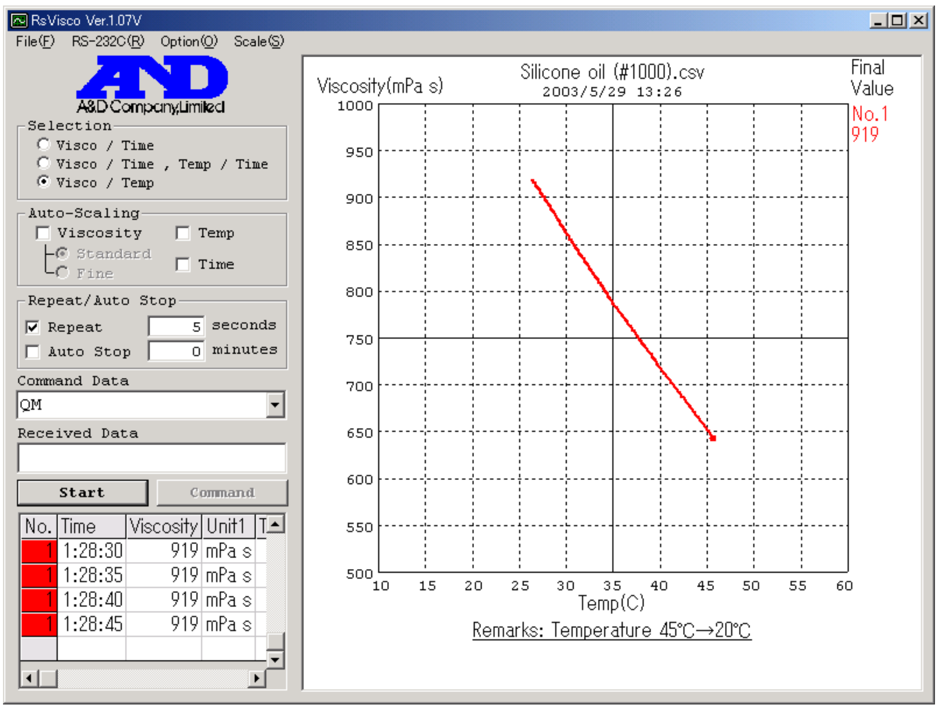



Figure 16 Correlation between Viscosity Change in Response to Temperature Change of Silicon Oil

**Example of Viscosity Measurement of Purified Water**

Figure 17 shows the result of SV-10A 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-10A enables correct viscosity measurement of samples of low viscosity.

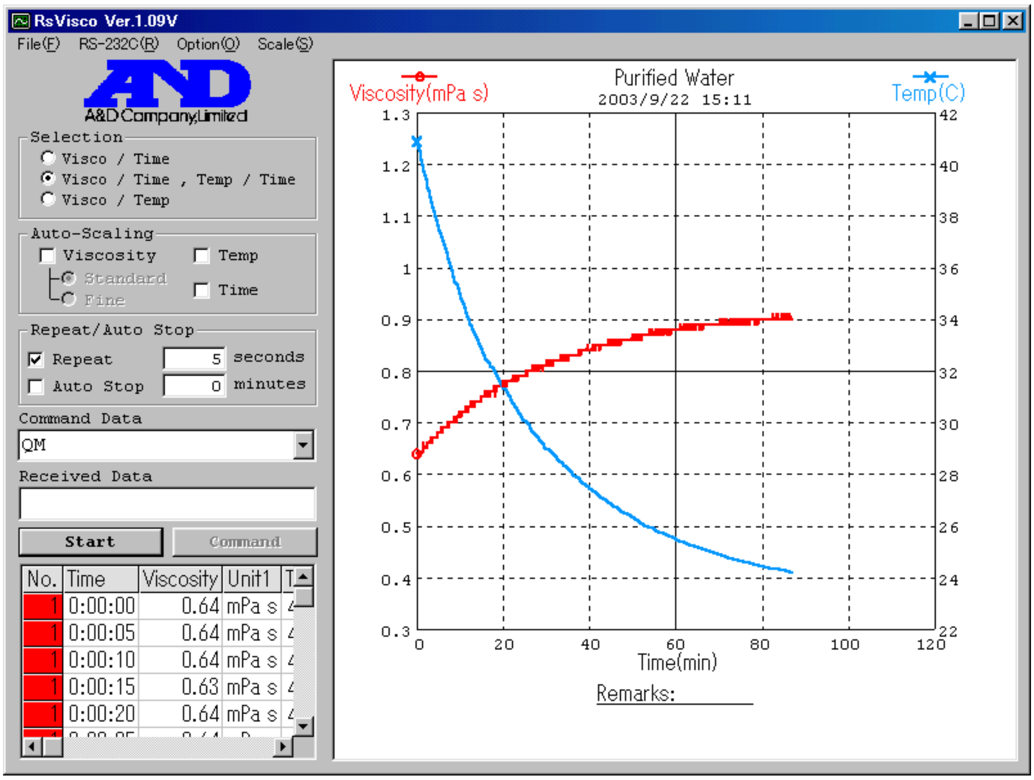



Figure 17 Example of Viscosity Measurement of purified water (SV-10A)

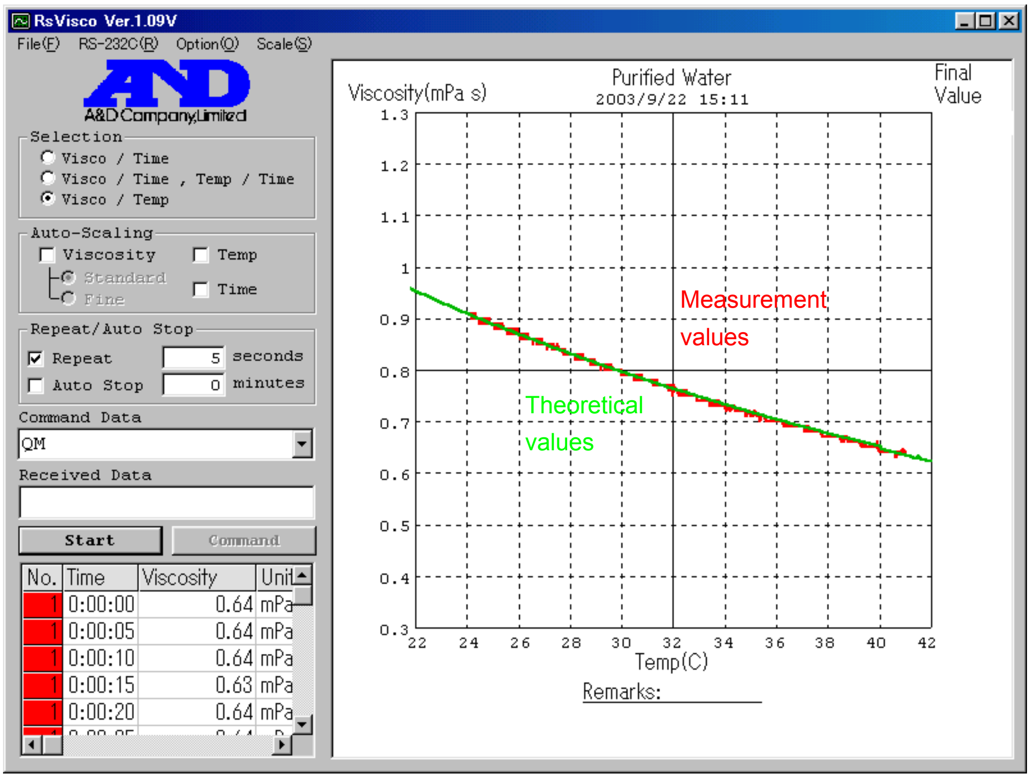



Figure 18 Example of Viscosity Measurement of purified water (SV-10A)

**(2) Viscosity Measurement Examples of Industrial Products**

Figure 19 shows the cure processes of four kinds of commercially-available, ready-mixed mortars at room temperature. Mortars are compound materials in which cements are mixed with sand, resinous bonding materials, etc. The cure process of each mortar material was observed by measuring the viscosity change immediately after the mortar material was mixed with its recommended amount of water. The results showed differences in cure process between the different mortar materials. In particular, a very fast curing was observed for Mortar 1, which was labeled "flash set."

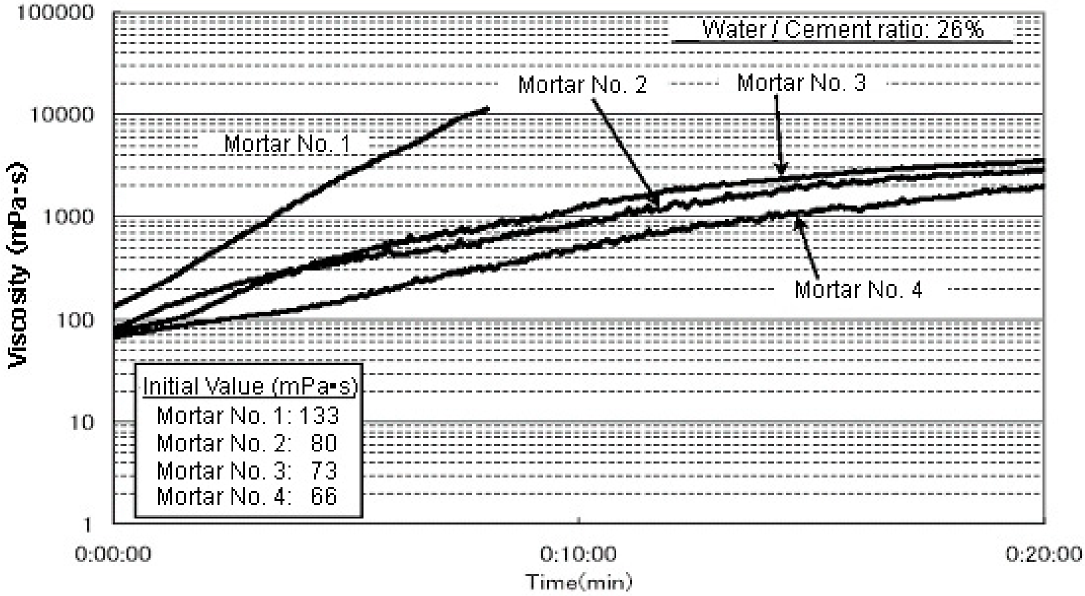



Figure 19 Viscosity Changes of Mixed and Kneaded Mortars (SV-10A)

Figure 20 shows the results of viscosity measurement at room temperature for raw cements mixed with water (cement pastes). Three cement pastes of different water-cement ratios were used. As shown in the graph, each cement paste has a different initial viscosity and fluidity depending on its water-cement ratio.

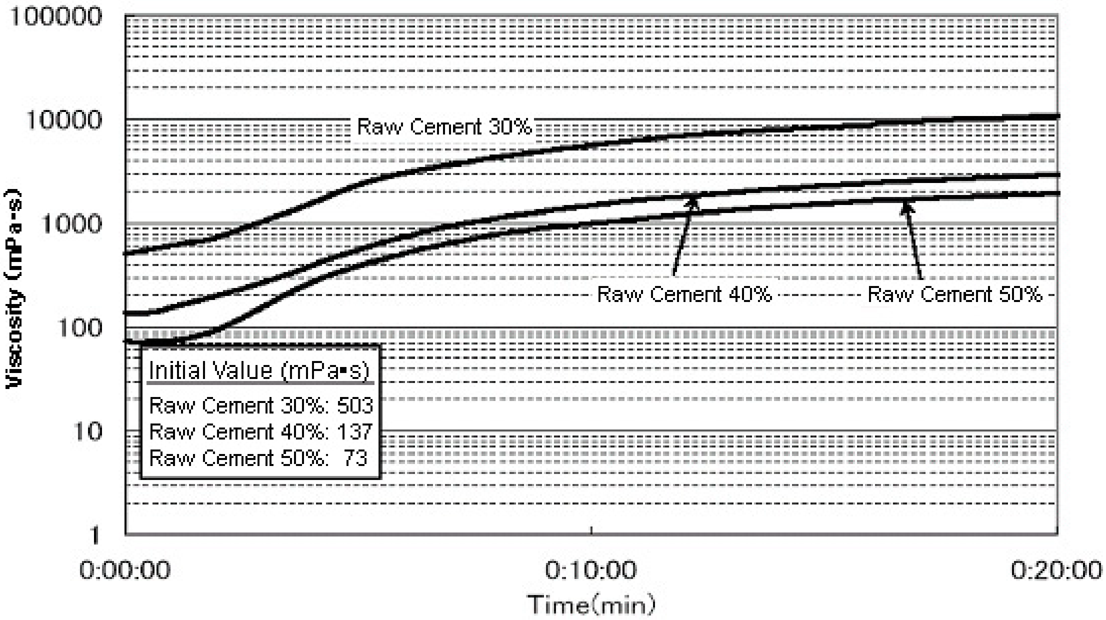



Figure 20 Viscosity Changes of Cement Pastes (SV-10A)

Using Mortar 1 (flash set), the influence of differences in water-cement ratio on the cure process was measured. As shown in Figure 21, the larger the water content, the longer it took the mortar material to cure. In particular, when the water content was 26% or below, the mortar increased its solidness rapidly, resulting in poor fluidity. In the 20% results, several small viscosity peaks were observed during the same cure process. These sudden viscosity changes were apparently caused by slipping between the mortar material and the sensor plates that were in direct contact with the sample.

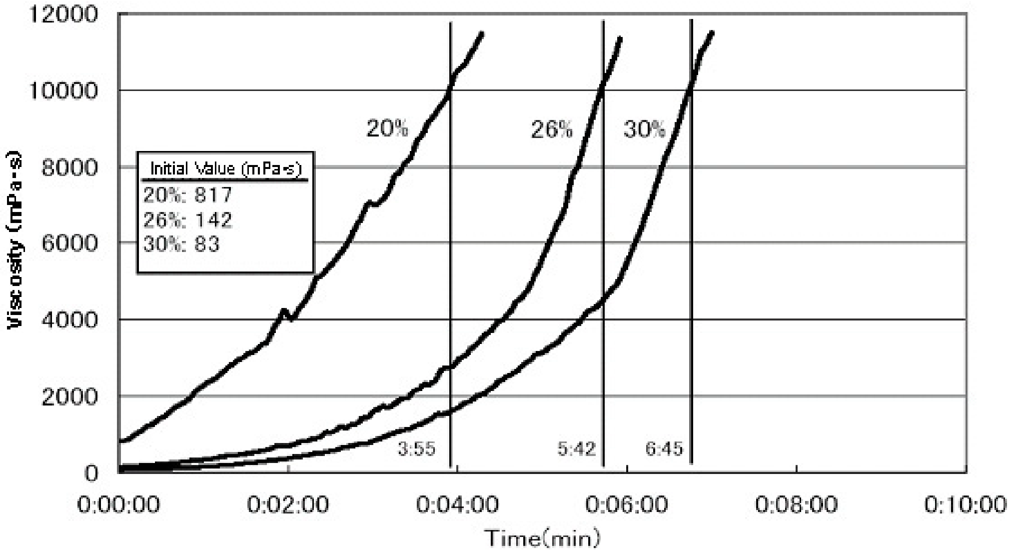



Figure 21 Differences in the Cure Process due to Different Mixing Ratios with Water (SV-10A)

Furthermore, Figure 22 shows the influence of ambient temperature on the cure process of Mortar 1 (flash set). The viscometer and the sample were placed inside a temperature-controlled room, where water and the mortar were mixed under different temperatures in order to measure the influence of differences in ambient temperature on curing. The graph indicates that curing was slow at a low temperature (10˚C) and fast at a high temperature (40˚C), and that changes in the curing speed of areas that change in temperature were determined to have a low progressivity. In addition, when the cure process is under a temperature of 40˚C, there was a viscosity variation at around 8,000 mPa･s, supposedly due to slipping between the sample and the sensor plates.

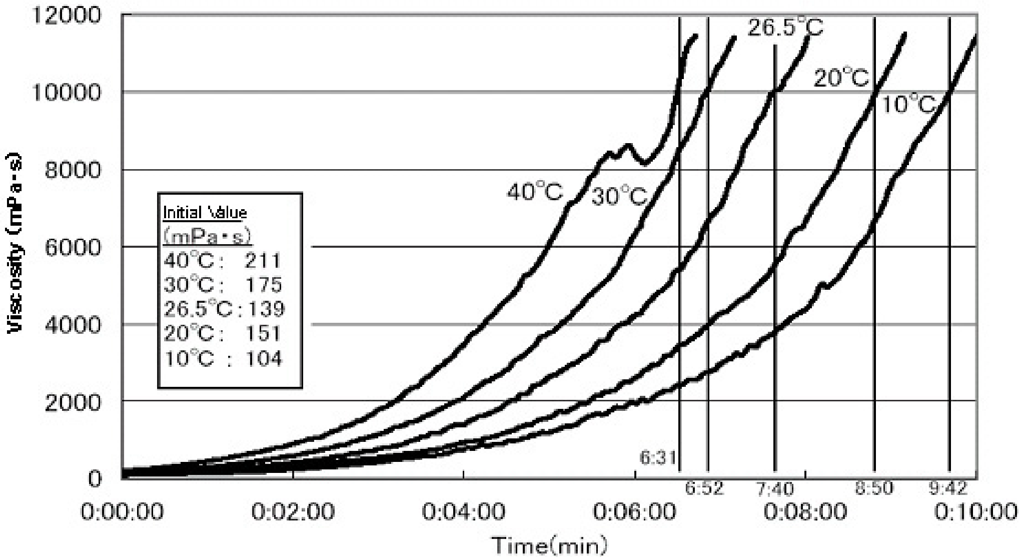



Figure 22 Cure Process of Mortar under Different Ambient Temperatures (SV-10A)

Figures 23 and 24 show the results of SV-10A 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-A Series can measure the process of temperature change, so you can easily find out the viscosity at a specific temperature.

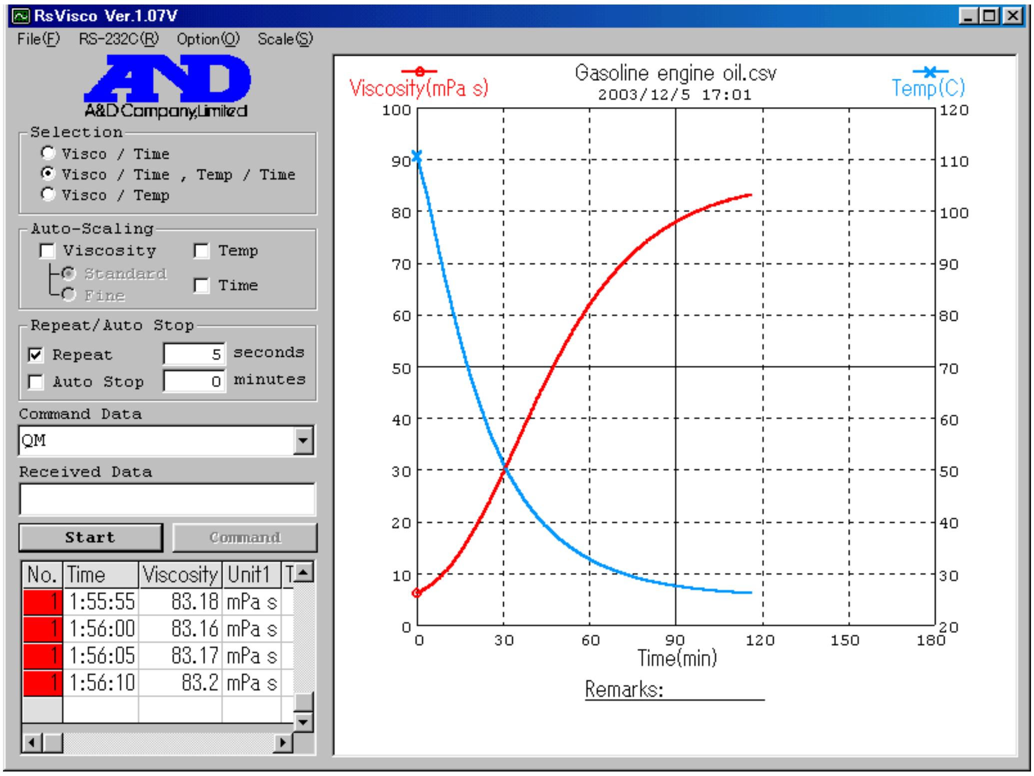



Figure 23 Viscosity Measurement Example of Gasoline Engine Oil (SV-10A)

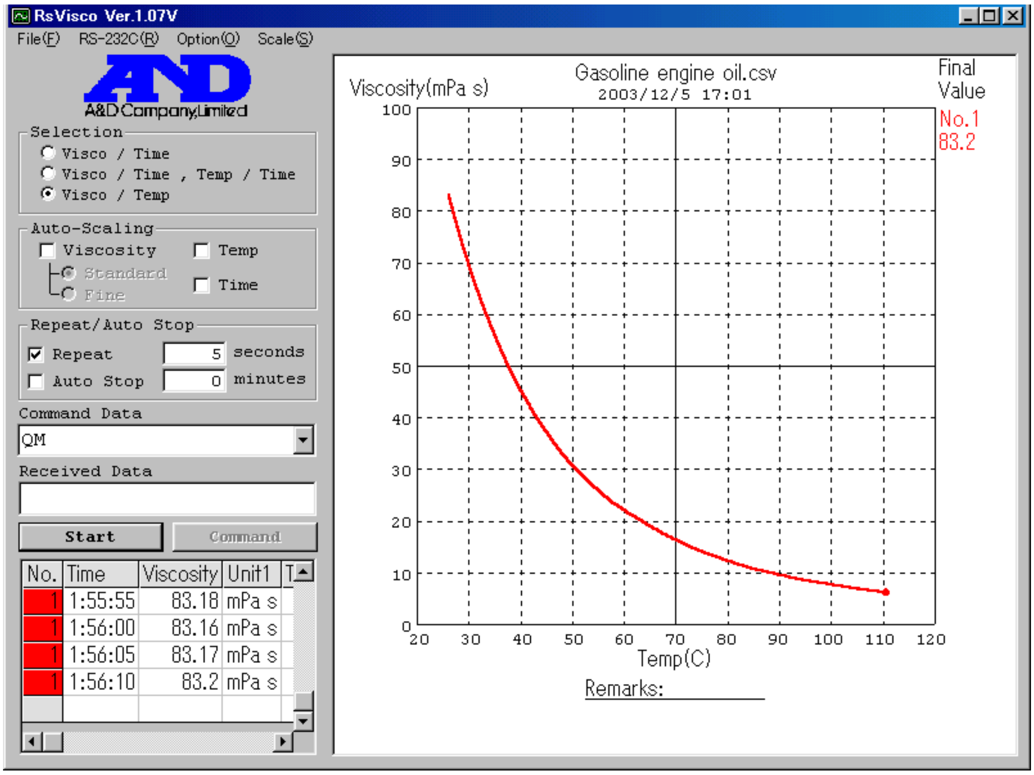



Figure 24 Correlation between Viscosity Change and Temperature Change of Gasoline Engine Oil (SV-10A)

Figure 25 shows the SV-10A measurement results of 3 types of semiconductor abrasive. The SV-10A can measure even a fluid of low viscosity and determine the original viscosity and degradation of abrasive.
Figure 26 shows the results of SV-10A 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.

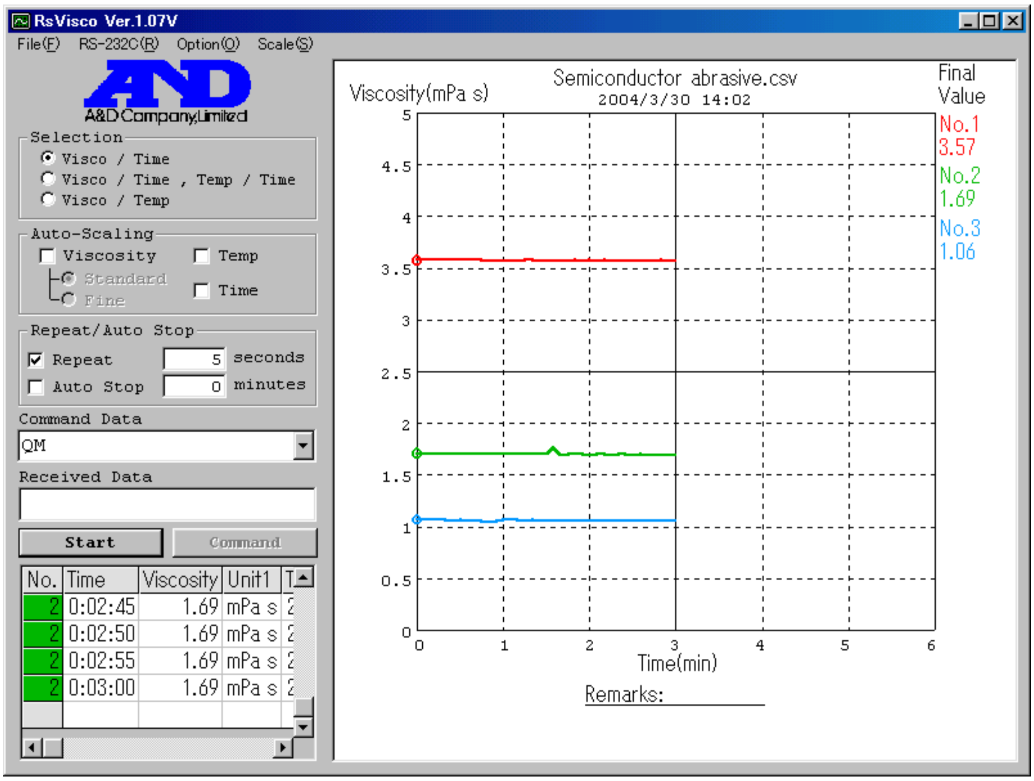



Figure 25 Measurement Example of Semiconductor Abrasive (SV-10A)

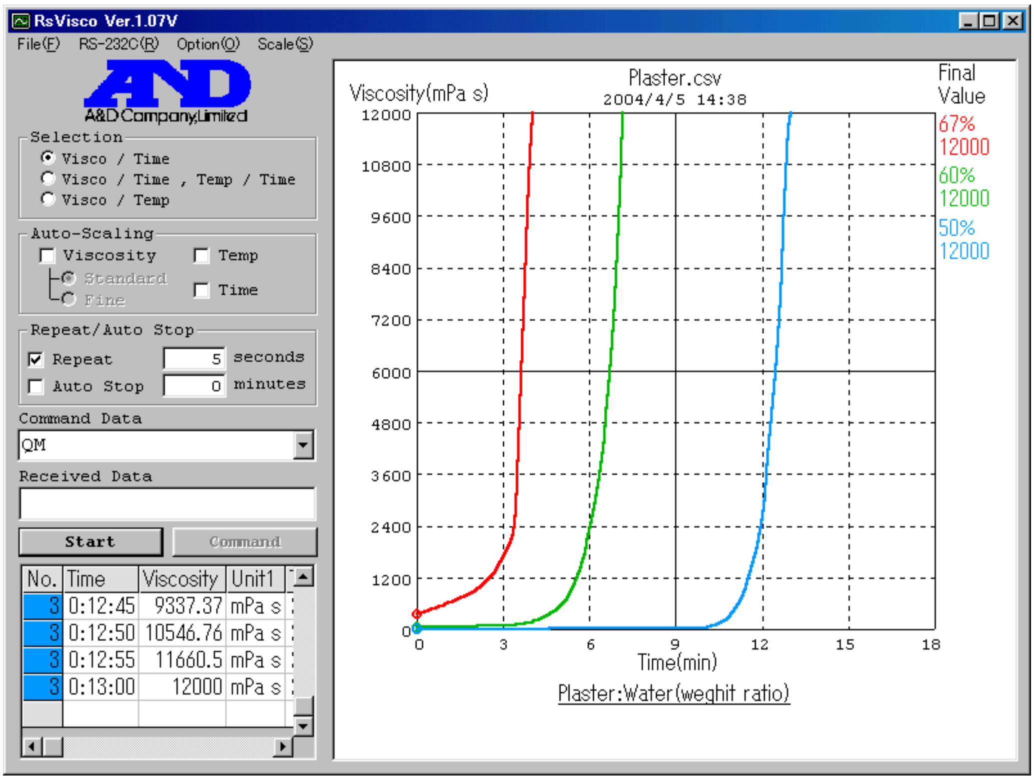



Figure 26 Measurement Example of Curing Process of Plaster (SV-10A)

Figure 27 shows the results of SV-10A 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°C.

Figure 28 shows the result of SV-100A 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-A Series can continuously measure over a long period of time.

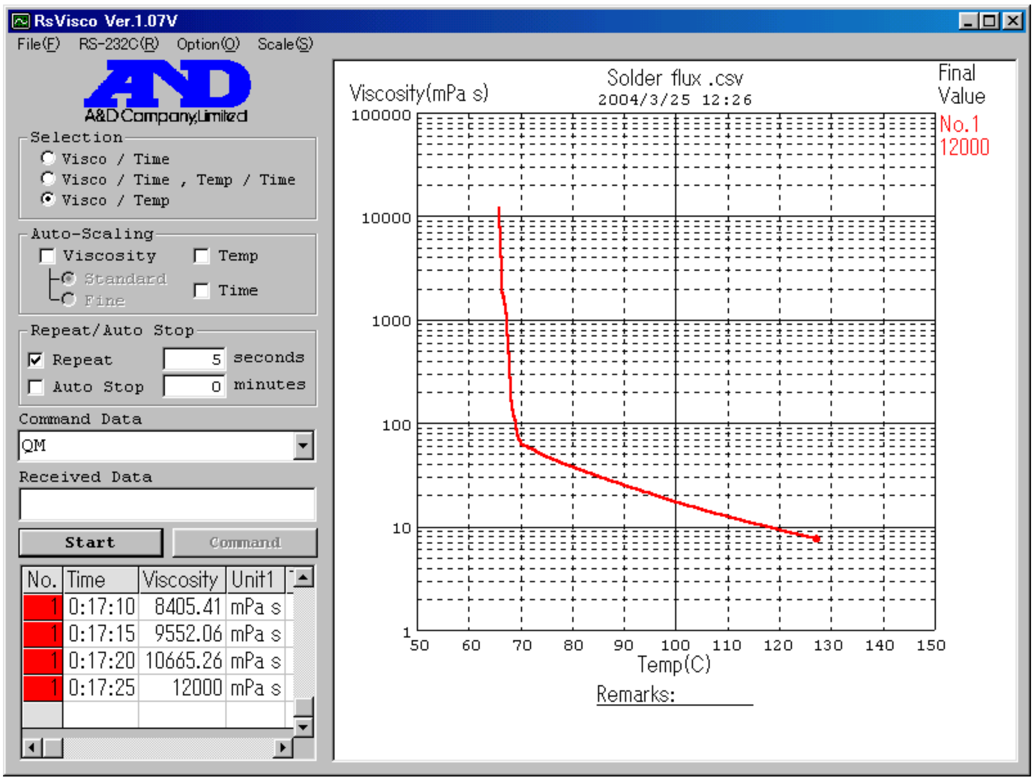



Figure 27 Measurement Example of Gelation Point of Solder Flux (SV-10A)

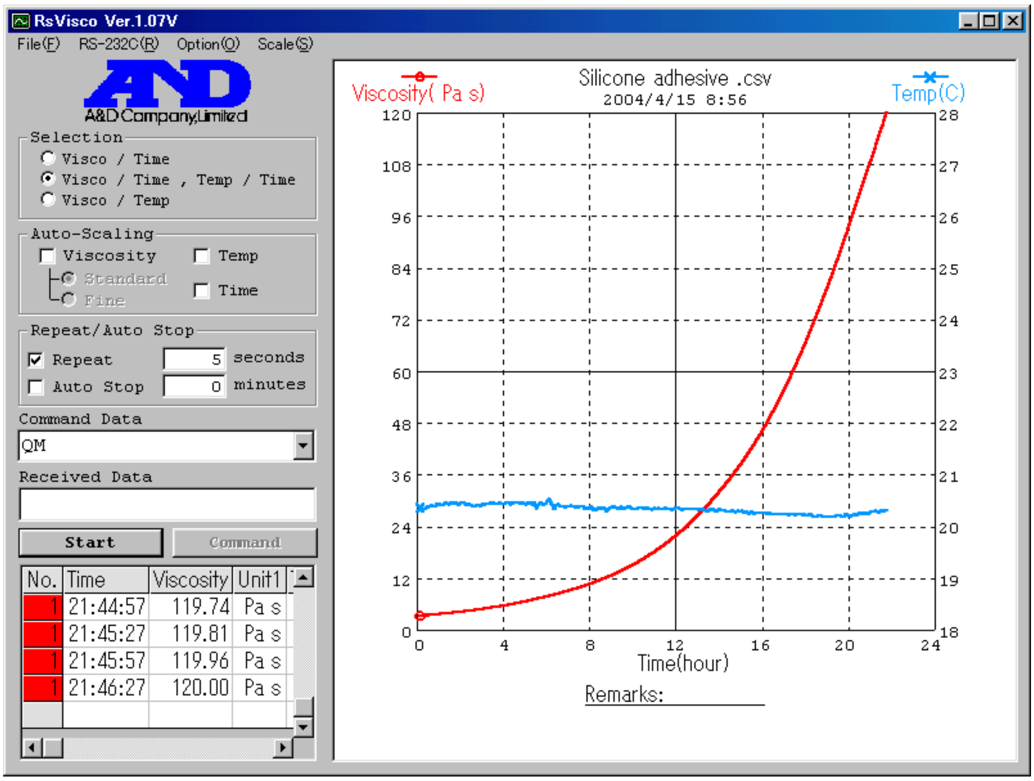



Figure 28 Measurement Example of Curing Process of Silicone Adhesive (SV-100A)

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-10A, 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 29 shows the results of SV-10A 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-10A can successfully measure the cloud point.

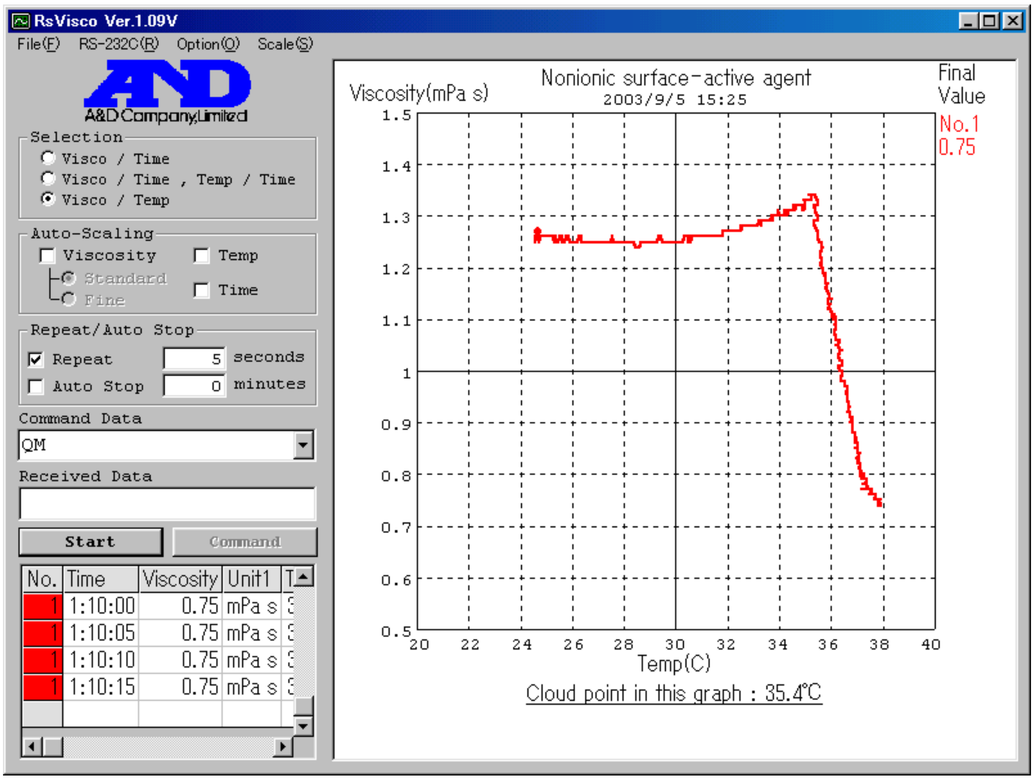



Figure 29 Measurement Example of Nonionic Surface-active Agent (SV-10A)

Figure 30 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 31 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.

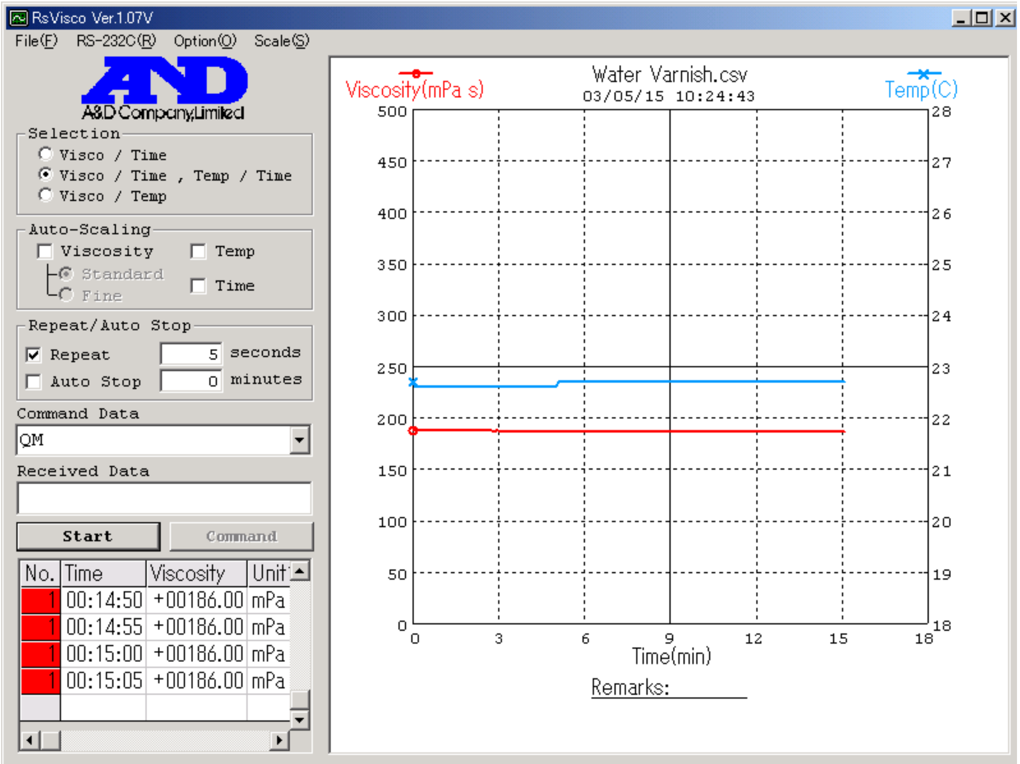



Figure 30 Example of Viscosity Measurement of Water-based Varnish (SV-10A)

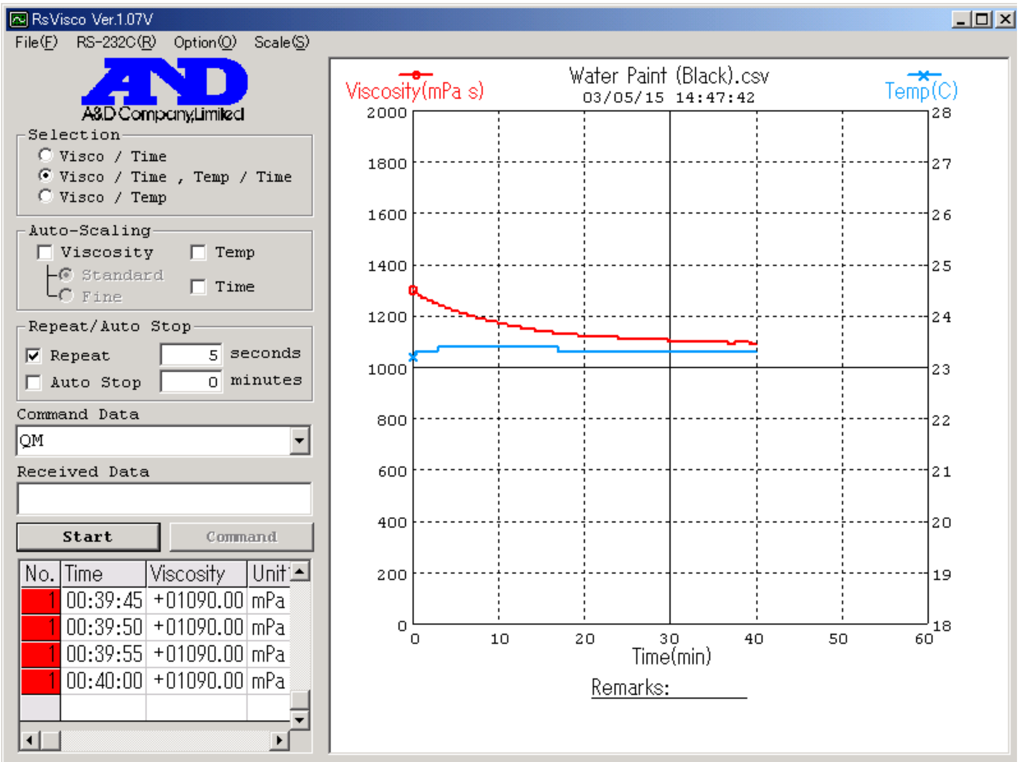



Figure 31 Example of Viscosity Measurement of Water-based Paint (SV-10A)

### (3) Viscosity Measurement Examples of Fluids of Different Concentrations

Figures 32 and 33 show the SV-10A 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.

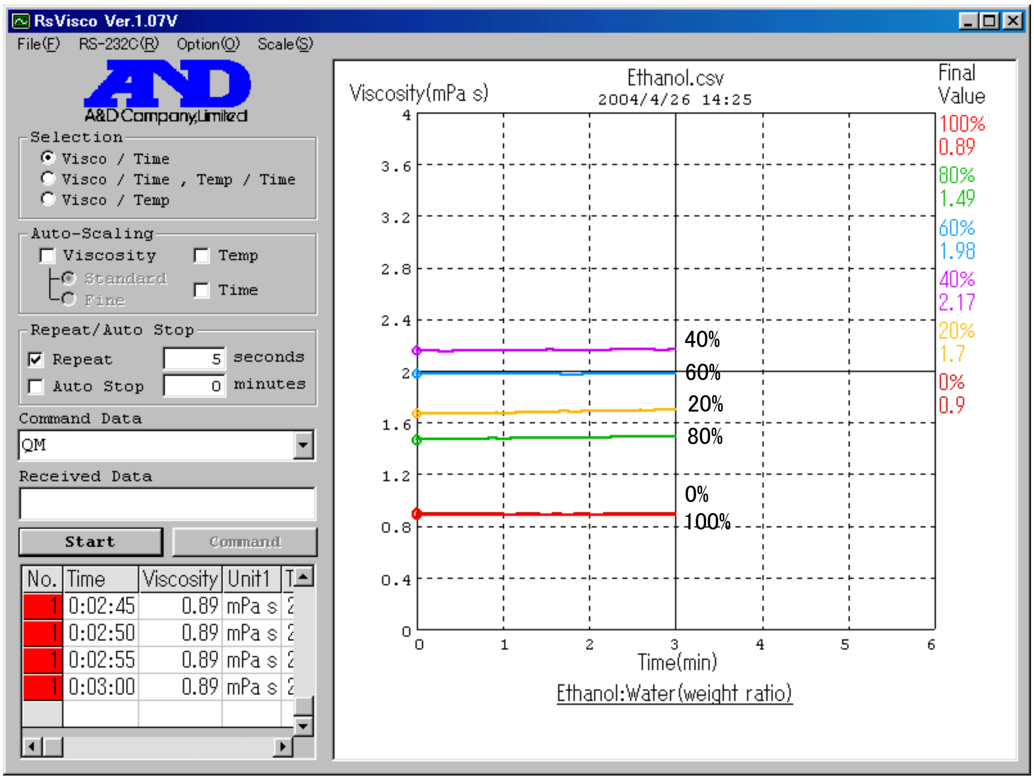
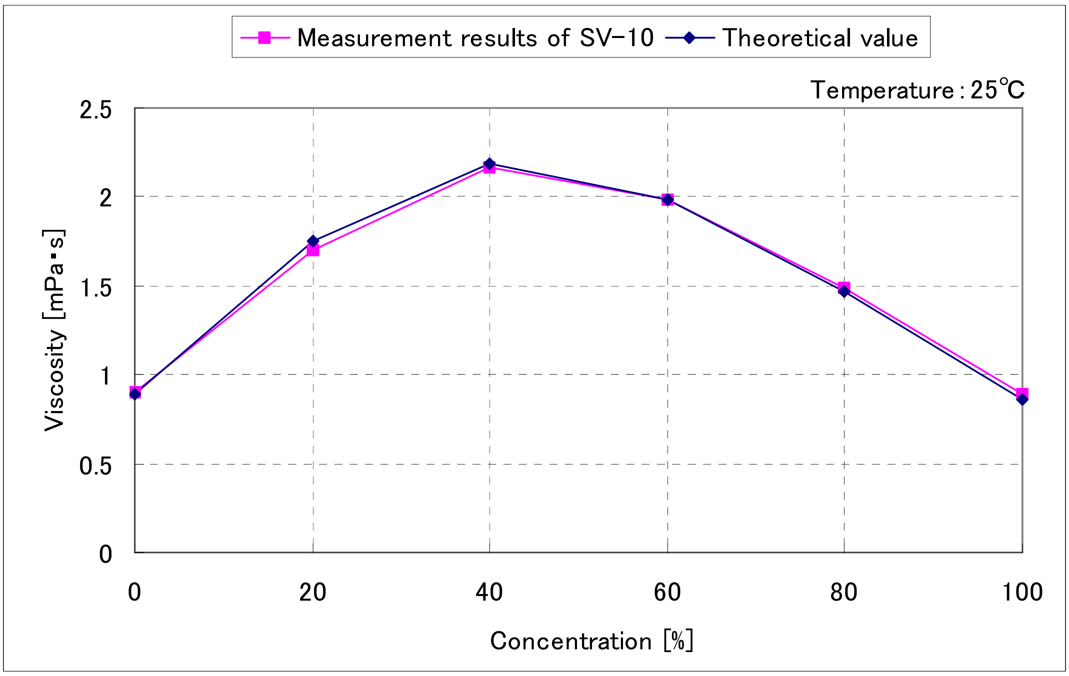



Figure 32 Measurement Example of Ethanol (SV-10A)




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

Figure 33 Relation between the Concentration and Viscosity of Ethanol Solution

Figure 34 shows the result of SV-10A measurement of die-cast mold release agent at each concentration diluted with water. It shows that the viscosity varies in response to concentration.
Figure 35 shows the result of SV-10A 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.

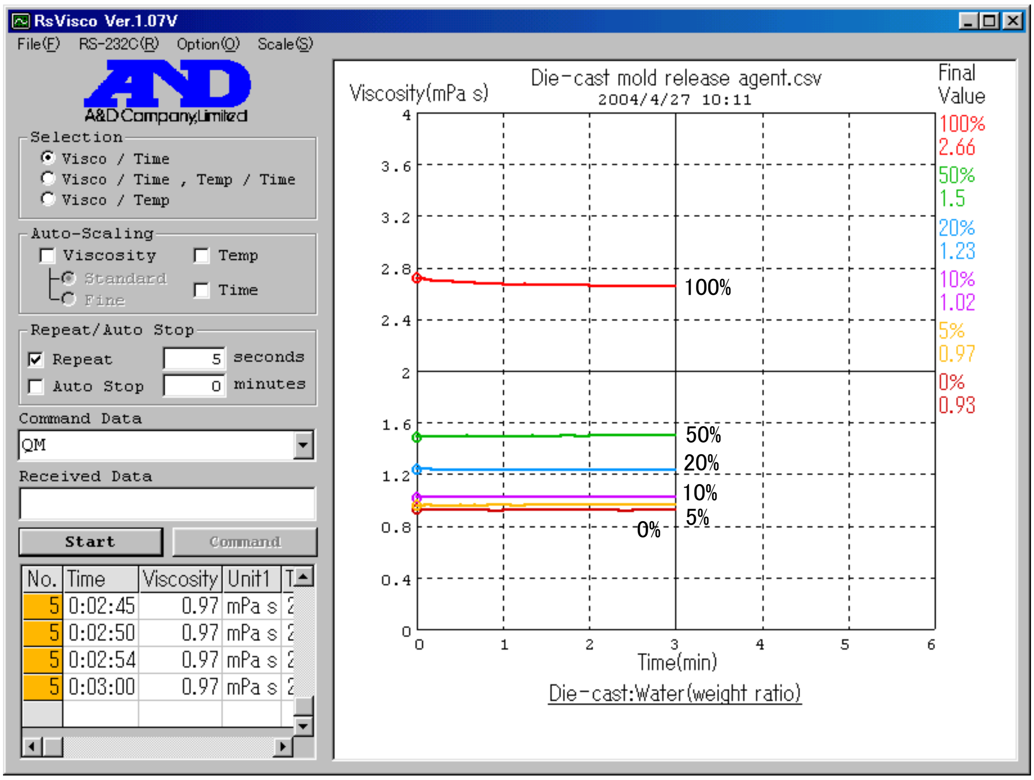



Figure 34 Measurement Example of Die-cast Mold Release Agent (SV-10A)

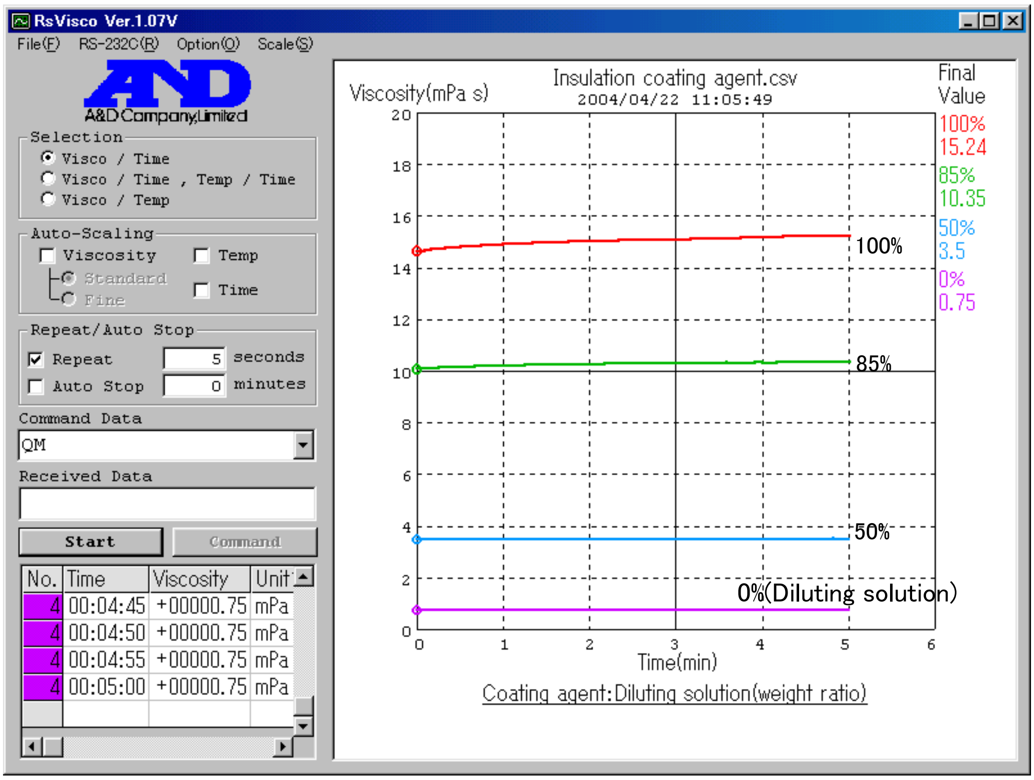



Figure 35 Measurement Example of Insulation Coating Agent (SV-10A)

### (4) Viscosity Measurement of Food

Figures 36 and 37 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.

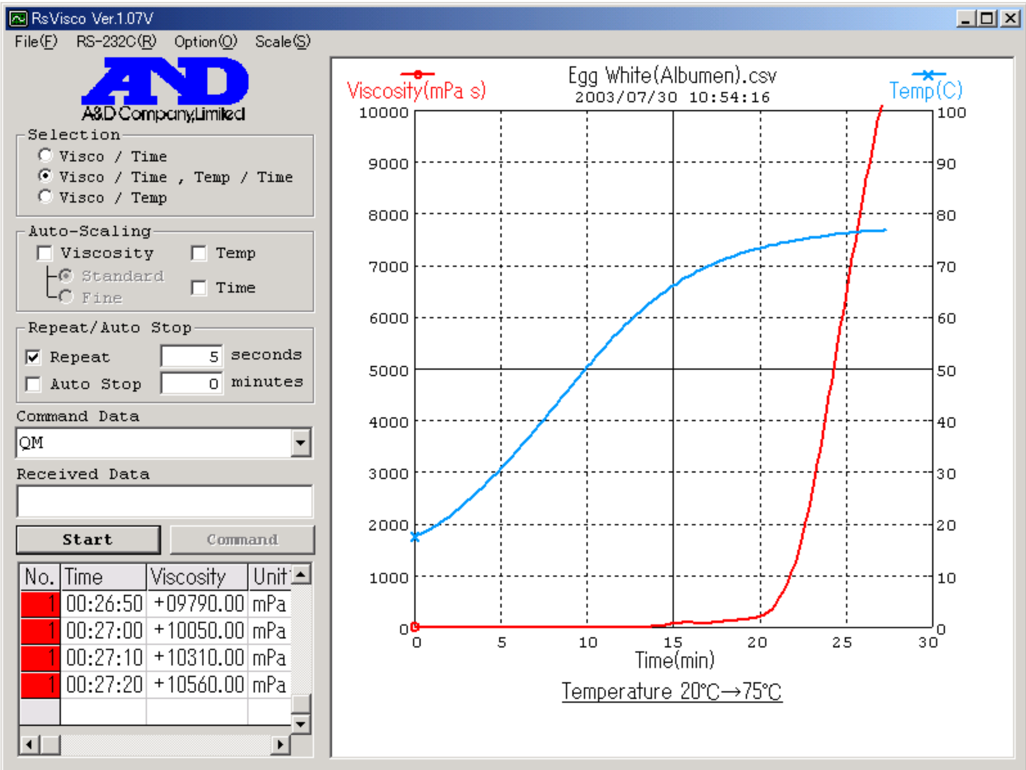



Figure 36 Example of Viscosity Measurement of Egg White (SV-10A)

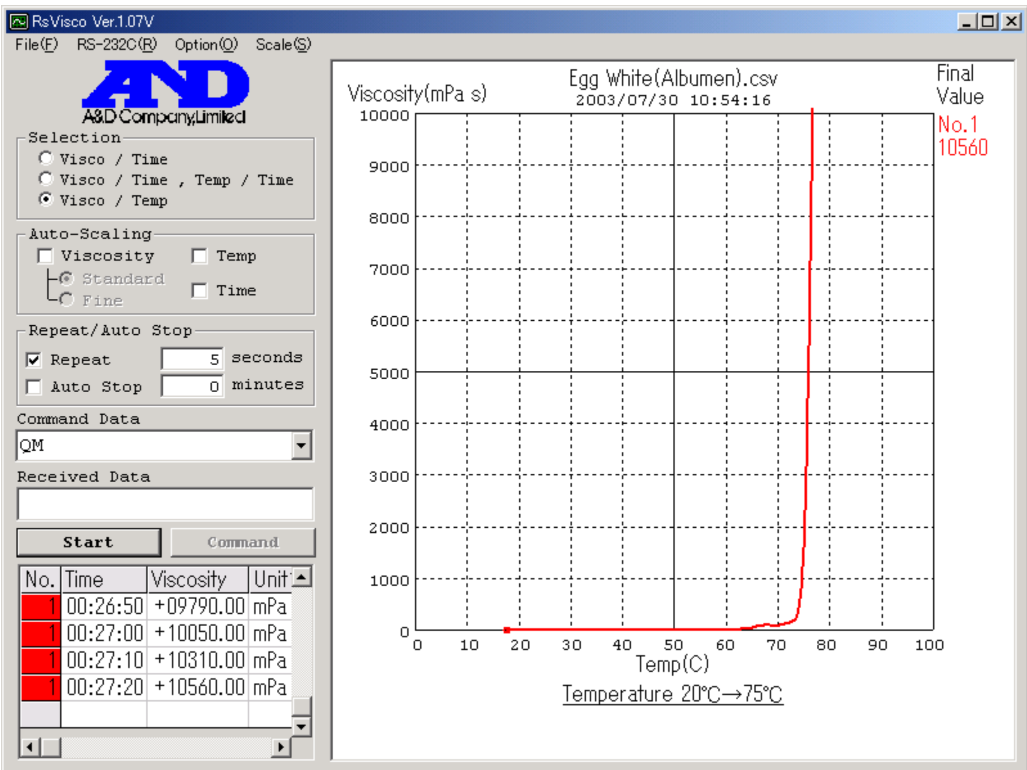



Figure 37 Increasing Process of Viscosity of Egg White with Temperature Increase (SV-10A)

Figures 38 and 39 show graphs representing the measurement results of the viscosity of egg white, shown in Figures 36 and 37, by indicating with logarithmic scale on the y-axes (viscosity). We can observe, especially in Figure 37, 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-A 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.

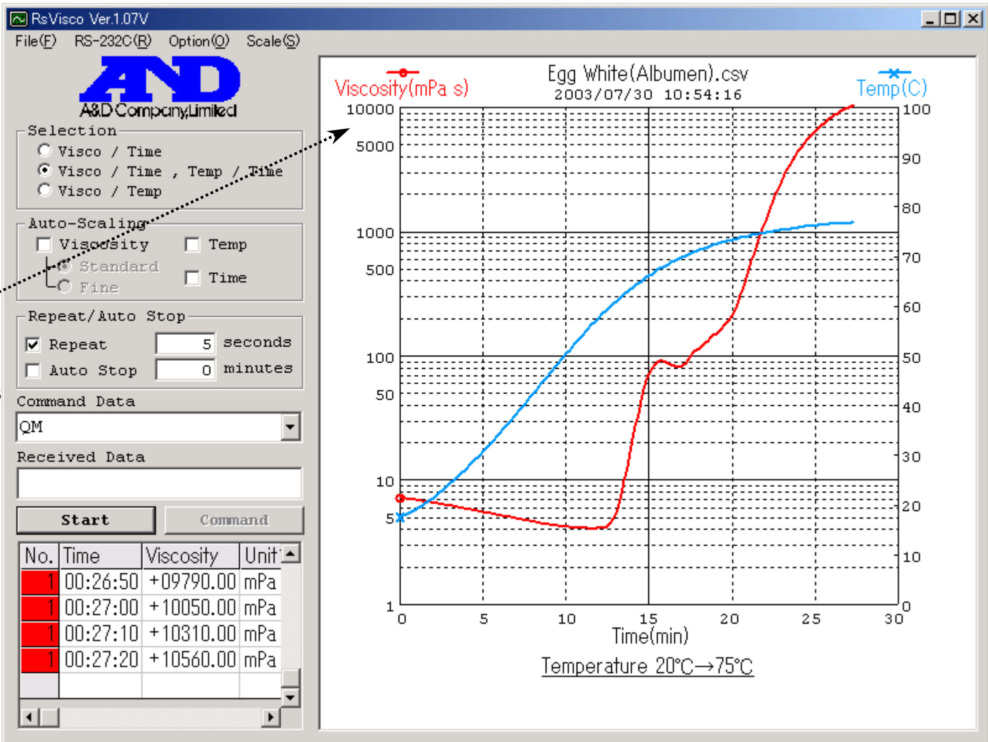



Figure 38 Example of Viscosity Measurement of Egg White (Log scale on the viscosity axis)

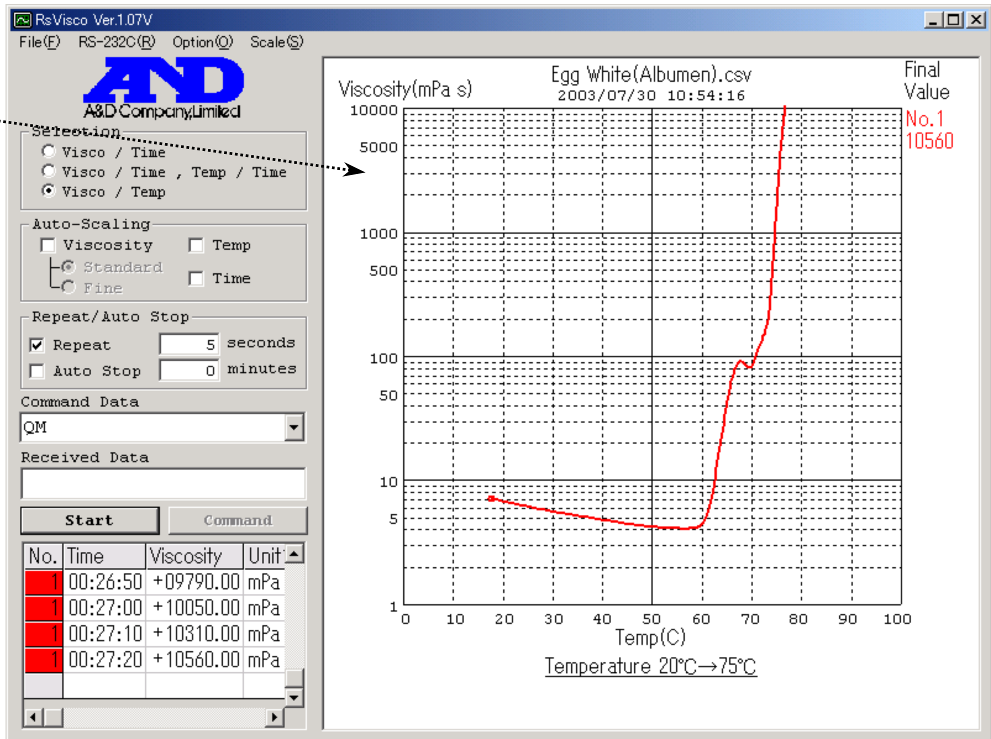
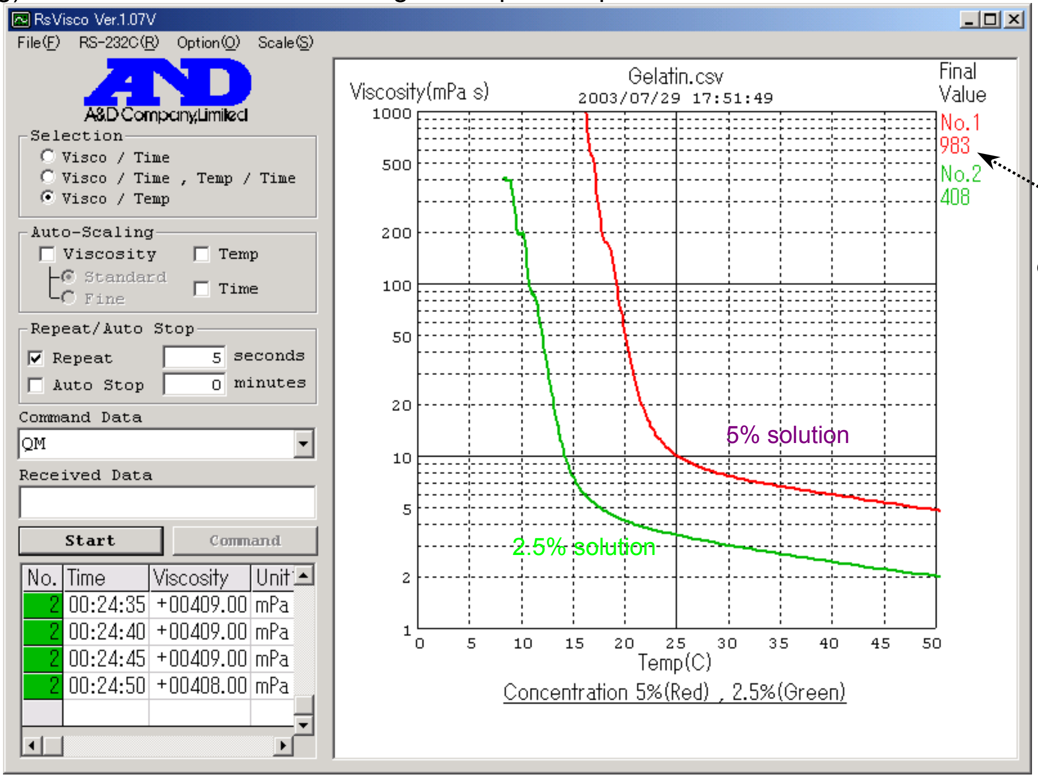



Figure 39 Progress of Viscosity Increase in Response to Temperature Increase of Egg White (Log scale on the viscosity axis)

Figure 40 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 40 Example of Viscosity Measurement of Gelatin of Different Concentration (Viscosity Axis Log Scale)

Figure 41 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-10A.

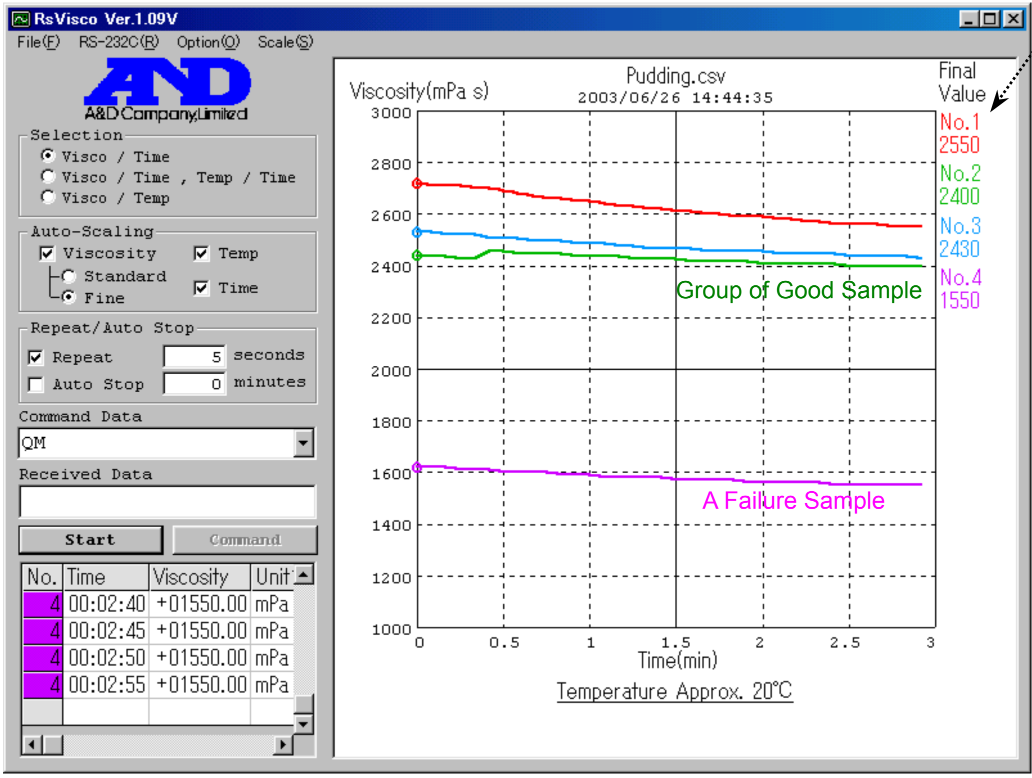
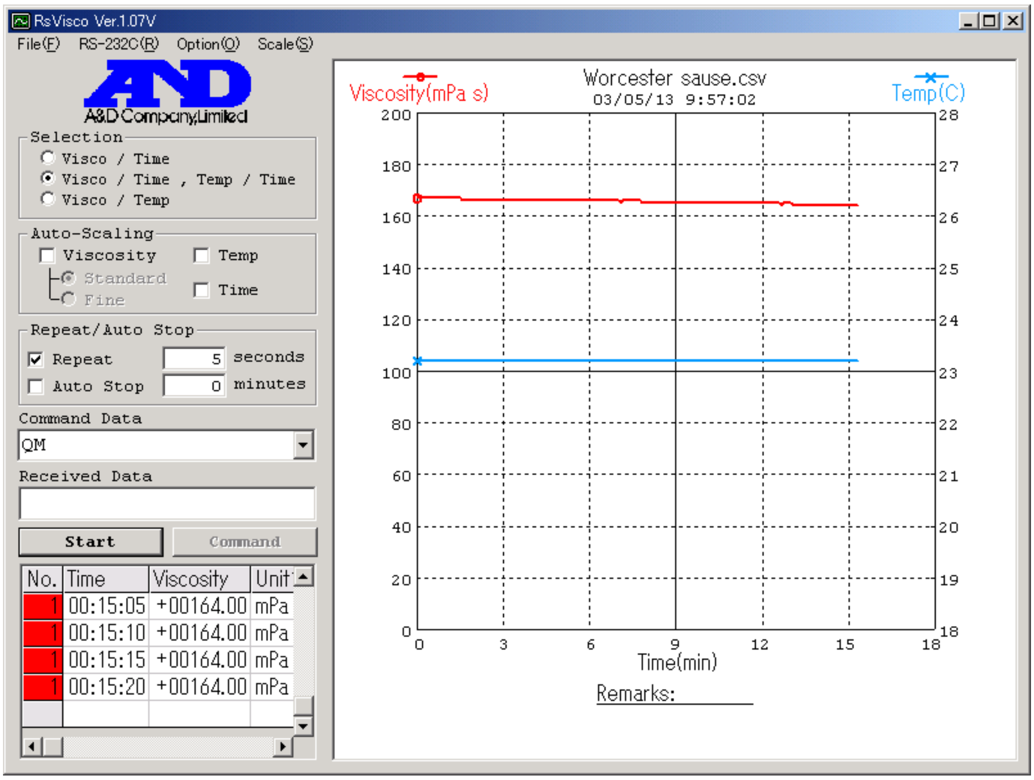



Figure 41 Example of Viscosity Measurement of Custard Pudding

Figure 42 shows a graph representing the measured result of Worcester sauce under fixed conditions (room temperature).
We can see from the SV-10A measurement that Worcester sauce shows a stable viscosity in response to the elapsed time.




<u>Figure 42</u> Example of Viscosity Measurement of Worcester Sauce (SV-10A)

(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

Using the SV-10A:

| 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.<br>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.<br>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.<br>Time to stabilization: 1 minute |
| 14 | Food product | Cold beverage (Jellylike) | 106 to 116 | 23.0 | Increases with time and then stabilizes.<br>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.<br>Time to stabilization: 6 minutes |
| 19 | Food product | Condensed milk | 1540 to 1470 | 23.3 | Decreases with time and then stabilizes.<br>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.<br>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.<br>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.<br>Time to stabilization: 20 minutes |
| 32 | Coating material | Red ink (Water dilution at 10% concentration) | 1.12 | 22.8 | No significant change over time. |

| 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 26) |
| 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. |

Using the SV-100A:

| 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. (Firure 28) |

(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:

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

Using the SV-10A:

| 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 |

Using the SV-100A:

| 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

Using the SV-10A:

| No. | Sample Name | Measurement method | Comments |
|---|---|---|---|
| 59 | Egg white | Heated with a heater. | Sets at about 60°C. (Figure 43) |
| 60 | Lard | Heated to about 70°C, then left to cool. | Sets at about 26°C. (Figure 44) |
| 61 | Dark chocolate | Heated to about 50°C, then left to cool. | Sets at about 25°C. (Figure 45) |
| 62 | Milk chocolate | Heated to about 50°C, then left to cool. | Sets at about 25°C. (Figure 45) |
| 63 | Gelatin (5% concentration) | Cooled with a temperature controller. | Gelates at about 20°C. (Figure 46) |
| 64 | Gelatin (2.5% concentration) | Cooled with a temperature controller. | Gelates at about 12°C. (Figure 46) |
| 65 | Lipstick | Heated to about 80°C, then left to cool. | Sets at about 65°C. (Figure 47) |
| 66 | Candle | Heated to about 110°C, then left to cool. | Sets at about 60°C. (Figure 48) |
| 67 | Solder flux | Heated to about 130°C, then left to cool. | Sets at about 70°C. (Figure 49) |
| 68 | Grease A | Heated to about 150°C, then left to cool. | Sets at about 100°C. (Figure 50) |
| 69 | Grease B | Heated to about 150°C, then left to cool. | Sets at about 90°C. (Figure 50) |
| 70 | Gasoline engine oil | Heated to about 110°C, then left to cool. | Viscosity at 40°C: 7.64 mPa·s<br>Viscosity at 100°C: 45.4 mPa·s<br>(Figure 51) |
| 71 | Diesel engine oil | Heated to about 110°C, then left to cool. | Viscosity at 40°C: 9.01 mPa·s<br>Viscosity at 100°C: 77.1 mPa·s<br>(Figure 52) |
| 72 | Nonionic surface-active agent (1% concentration) | Heated with a temperature controller. | Cloud point based on the JIS* regulations: 35.9°C.<br>Measurement result with the SV-10: 35.4°C.<br>(Figure 53) |

* JIS = Japanese Industrial Standards

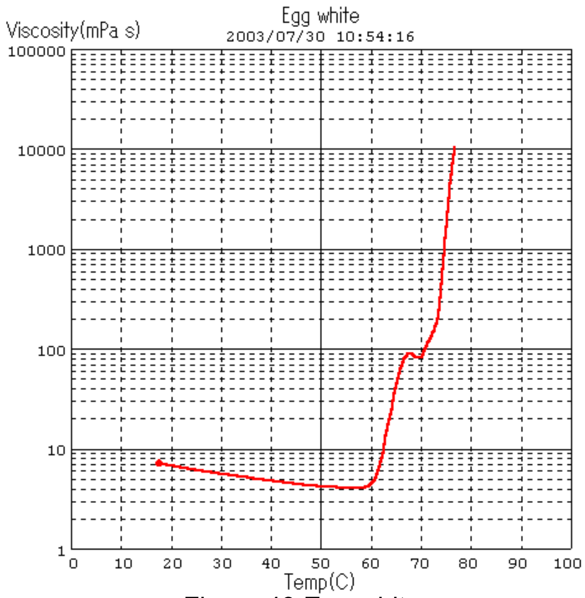



Figure 43 Egg white

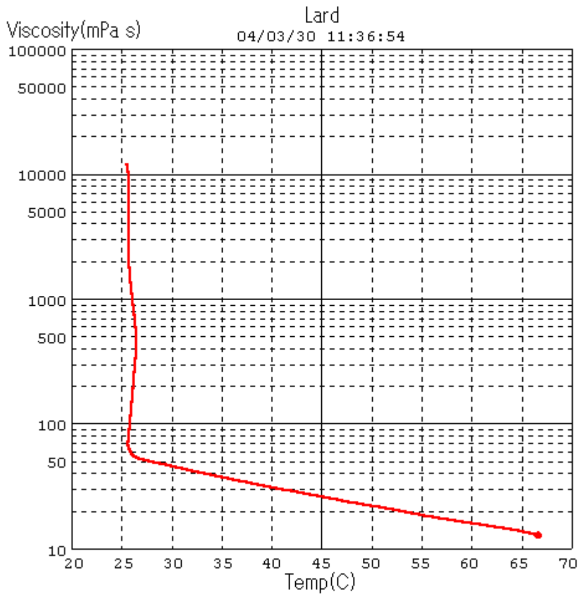



Figure 44 Lard

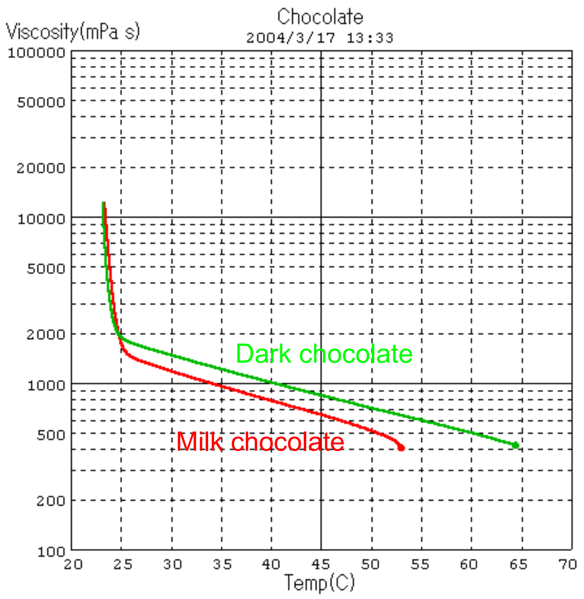



Figure 45 Chocolate

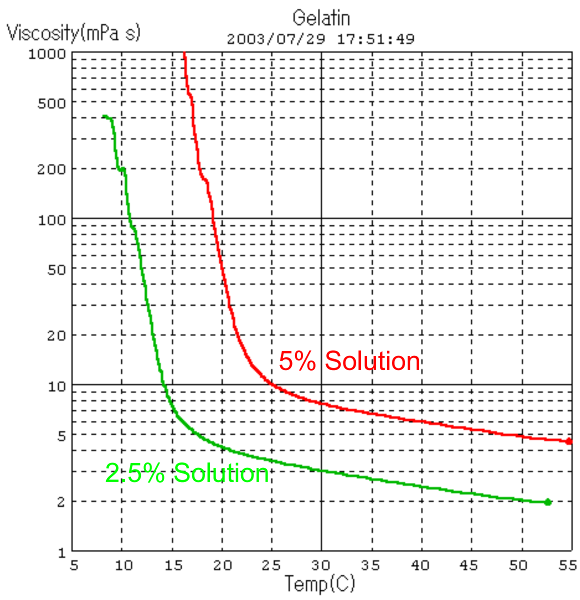



Figure 46 Gelatin

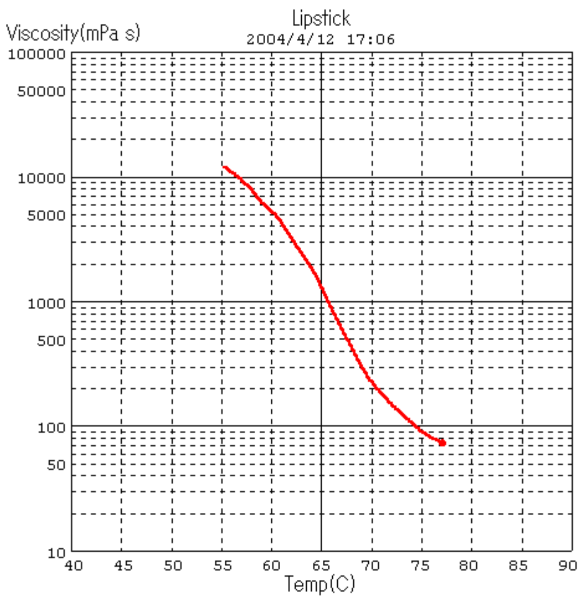



Figure 47 Lipstick

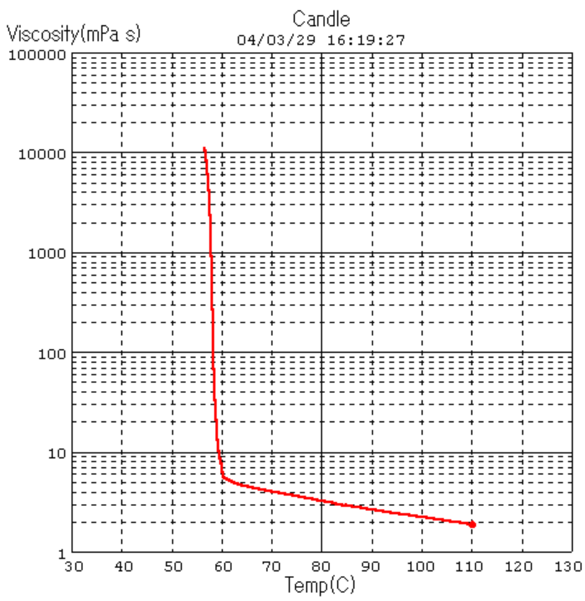



Figure 48 Candle

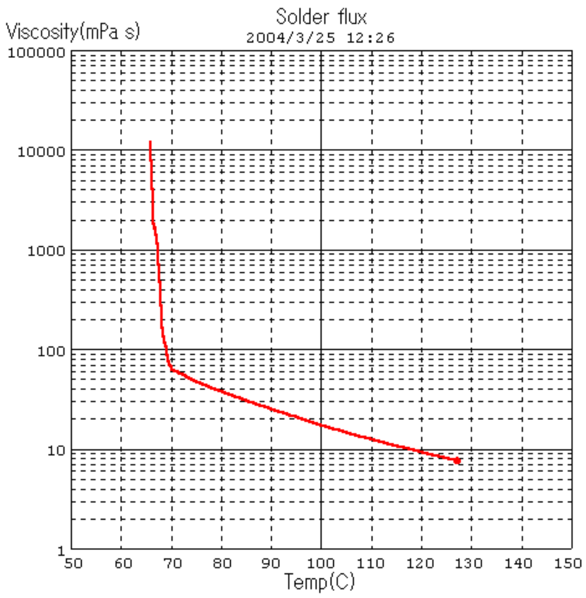



Figure 49 Solder flux

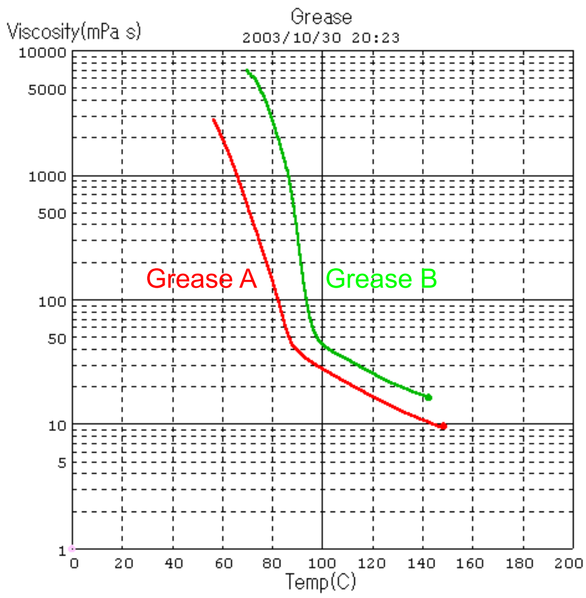



Figure 50 Grease

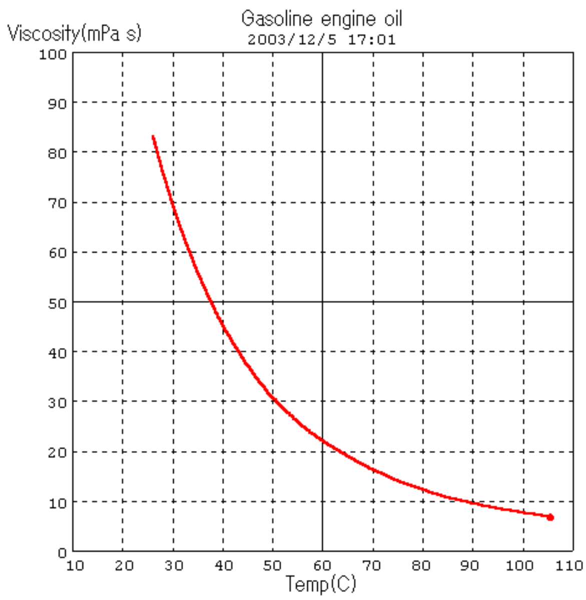



Figure 51 Gasoline engine oil

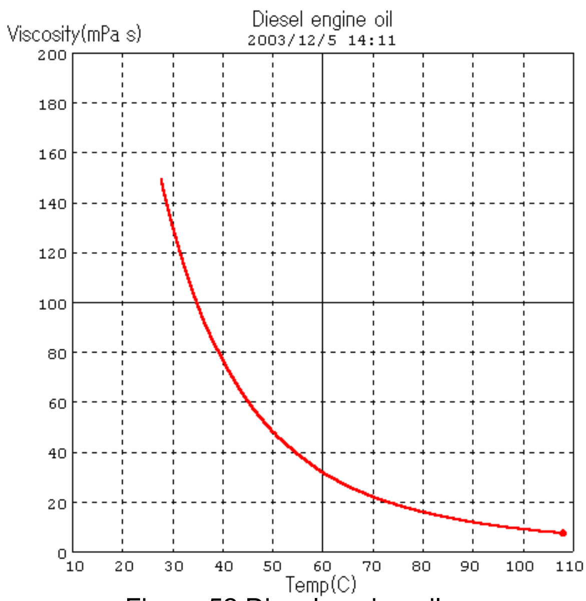



Figure 52 Diesel engine oil

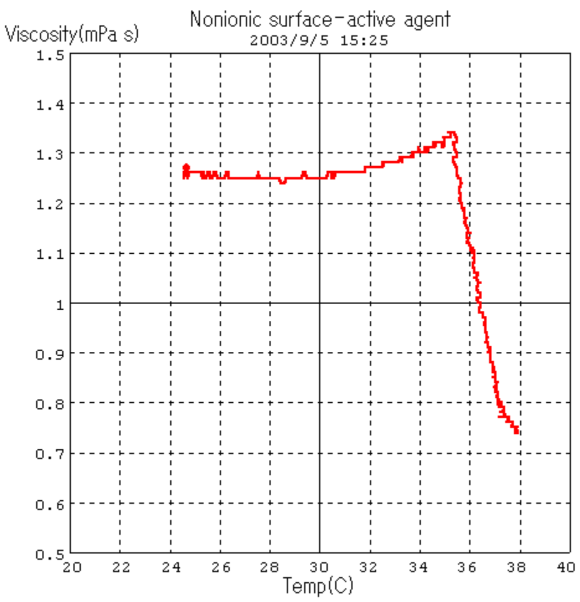



Figure 53 Nonionic surface-active agent

(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

Using the SV-10A: (Figure 32,33)

| 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

Using the SV-10A: (Figure 34)

| 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

Using the SV-10A: (Figure 35)

| 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 |

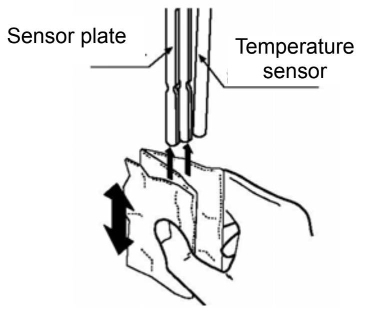
## ■Maintenance

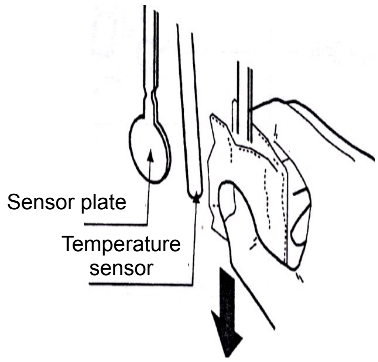
### A. Sensor Plate

| No. | Question | Answer |
|---|---|---|
| 35 | 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 |
|---|---|---|
| 36 | 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.<br>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.<br><br>How to clean: As shown in the figures on the right, 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.<br>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.<br>If the sample residue is difficult to wipe off, use a commercially-available ultrasonic cleaner. |



## C. Troubleshooting

| No. | Question | Answer |
| --- | --- | --- |
| 37 | When measurement values are not stable. | Is the ambient environment free from vibration and/or drafts?<br>●Use the anti-vibration table, AD-1685 (optional).<br>●Avoid direct drafts in the vicinity of the viscometer.<br>●Reconsider the setting of "Condition" of the function setting.<br><br>Is there a strong electrical or magnetic noise source such as a motor near the viscometer?<br><br>Is the protector or sensor protective cover in contact with the sensor plates or the temperature sensor?<br>●Attach the protector and the sensor protective cover properly so that they do not touch the sensor plates or temperature sensor.<br>●Remove the protector or the sensor protective cover when necessary.<br><br>With SV-1A, if the sensor plate touches the inner wall of the 2 mL cup, the displayed value will not stabilize. Adjust the spacing between the sensor plate and the inner wall of the 2 mL cup.<br><br>When tap water is poured into the sample cup directly and is measured, bubbles are generated on the sensor plates due to the difference in pressure and temperature and the viscosity may increase gradually. Pressurized tap water generates bubbles easily. Therefore, use distilled or purified water that is not pressurized. Furthermore, leave the sensor plates and sample in the same environment to acclimatize before measuring to decrease temperature fluctuations. |

| No. | Question | Answer |
| --- | --- | --- |
| 38 | When measurement values are incorrect. | Has the sample surface been adjusted to the center of the narrow part of the sensor plates?<br>●Adjust the table height by turning the knob so that the center of the narrow part of the sensor plates is on the sample.<br>Are the positions of the left and right sensor plates in the sample surface level?<br>●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.<br>Are the sensor plates bent?<br>●If bent, contact your local A&D dealer for repair.<br>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?<br>Has calibration been performed?<br>●When the absolute viscosity value is important, it is recommended that periodic calibration be performed using a standard viscosity fluid. |
| 39 | When the temperature values are incorrect. | Is the display unit connected to the main unit properly with the connection cable?<br>Since the measurement unit and display unit are adjusted as a pair, you should not perform adjustment of units with different serial numbers. |
| 40 | 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.<br>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-A Series

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

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

Viscosity Measurement Repeatability: 1% (Standard deviation)

Minimum Display

| | SV-1A | | SV-10A | | SV-100A |
|---|---|---|---|---|---|
| Viscosity | Min. Unit | | Min. Unit | | Min. Unit |
| (mPa·s) | (mPa·s) | (Pa·s) | (mPa·s) | (Pa·s) | (Pa·s) |
| 0.3-10 | 0.01 | 0.0001 | 0.01 | 0.0001 | – |
| 10-100 | 0.1 | 0.0001 | 0.1 | 0.0001 | – |
| 100-1000 | 1 | 0.001 | 1 | 0.001 | – |
| 1000-10000 | – | – | 10*[1] | 0.01 | 0.01 |
| 10000-100000 | – | – | – | – | 0.1 |

*[1] Here, the unit changes to Pa•s.

Units (Viscosity): mPa•s*[2], Pa•s, cP*[2], P — *[2] Only SV-1A/10A

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

Minimum Sample Amount: 2 ml or more*[3], 10 ml or more — *[3] Only SV-1A

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)
±4°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:
Sensor unit 112 (W) × 132 (D) × 291 (H) mm/Approx. 5.0 kg
Display unit 238 (W) × 132 (D) × 170 (H) mm/Approx. 1.3 kg

Standard Accessories for all units:
AC adapter (1 pc.)
Connection cable (1.5m, 1 pc.)
Carrying case

Option:
AX-SV-31-2.5 Standard viscosity fluid (JS2.5)
AX-SV-31-5 Standard viscosity fluid (JS5)
AX-SV-31-10 Standard viscosity fluid (JS10)
AX-SV-31-20 Standard viscosity fluid (JS20)
AX-SV-31-50 Standard viscosity fluid (JS50)
AX-SV-31-100 Standard viscosity fluid (JS100)
AX-SV-31-200 Standard viscosity fluid (JS200)
AX-SV-31-500 Standard viscosity fluid (JS500)
AX-SV-31-1000*[4] Standard viscosity fluid (JS1000)

AX-SV-31-2000*[5] Standard viscosity fluid (JS2000)

AX-SV-31-14000 Standard viscosity fluid (JS14000)

AX-SV-31-160000*[6] Standard viscosity fluid (JS160000)

*[4] For the SV-10A only

*[5] Temperature should be kept at or below 25°C when performing calibration with the SV-100A.

*[6] For the SV-100A only

AX-SV-33 Sample Cup, 45 ml, Polycarbonate × 10 pcs

AX-SV-34 Small Sample Cup, 10 ml, with Cover, Polycarbonate × 10 pcs.

AX-SV-35 Sample Cup, 13 ml, Glass × 1 pc

AX-SV-36 Positioning Stopper × 1 pc

AX-SV-37 Water jacket (body:polycarbonate, packing:silicon gum), with 4 sets of a small sample cup and a lid

AX-SV-38 Storage Container, 60 ml, Glass × 10 pcs

AX-SV-39 Storage Container, 120 ml, Plastic × 20 pcs

AX-SV-42 Analogue voltage output (0 - 1V)

AX-SV-43 Extension cable (5m) to connect the sensor unit to the display unit

AX-SV-51 Stand Set with X-Y-Z Stage

AX-SV-52 X-Y-Z Stage × 1 pc

AX-SV-53-EX Software Set (WinCT-Viscosity × 1 pc, 25P-9P RS-232C Cable × 1 pc, Serial-USB Converter × 1pc)

AX-SV-54 Cup Set for SV-10A/100A
45 ml, Polycarbonate × 5 pcs / 10 ml, with cover, Polycarbonate × 5 pcs / 13 ml, Glass × 2 pcs / Glass sample cup holder, Stainless steel × 1 pc / Water jacket × 1 pc

AX-SV-55 Cup Set for SV-1A
45 ml, Polycarbonate × 5 pcs / 2 ml, with lid, Polycarbonate × 10 pcs
2 ml, Glass × 10 pcs / 2ml sample cup holder, Polycarbonate × 5 pcs
2ml sample cup stand × 1 pc / Water jacket × 1 pc

AX-SV-56-1 2ml Sample Cup Holder, Polycarbonate, Transparent × 5 pcs*[7]

AX-SV-56-2 2ml Sample Cup Holder, Polycarbonate, Black × 5 pcs*[7]

AX-SV-57 2ml Sample Cup Stand × 2 pcs*[7]

AX-SV-58 Sample Cup, 2ml with Lid, Polycarbonate × 100 pcs*[7]

AX-SV-59 Sample Cup, 2ml, Glass × 5 pcs, 2ml Sample Cup Stand × 1 pc*[7]

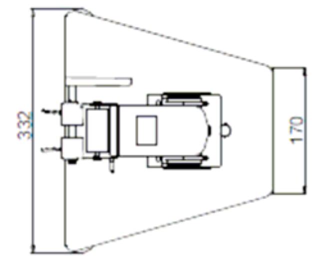
AD-8121B Compact printer

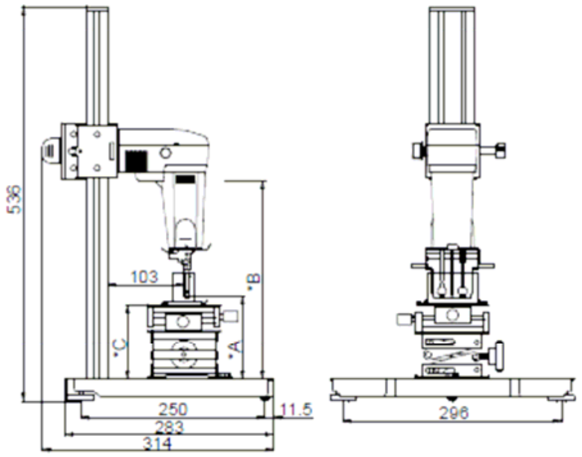
AD-1682 Rechargeable Battery

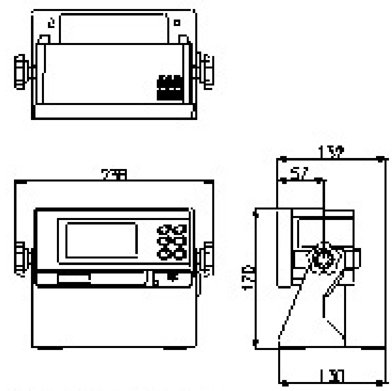
AD-1685 Anti-Vibration Table

*[7] for the SV-1A only

## Dimensions



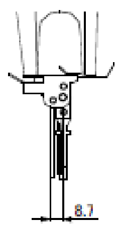



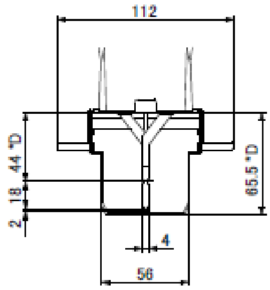

(Connection cable: 1.5m)

*A=Sensor plates lowest position 3.5 mm (With protector used, no table)
*B=Sensor plates highest position 268 mm
*C=Table height 54 to 140 mm

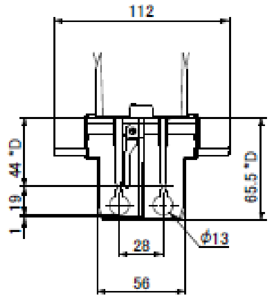
Unit: mm

### Detailed View of the Sensor Unit

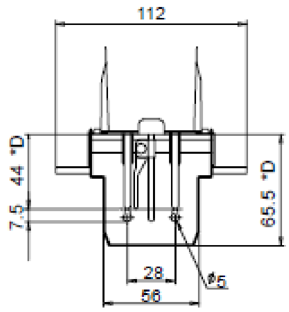



SV-1A/SV-1H




SV-10A/SV-10H




SV-100A/SV-100H

*D=Distance from the sensor protective cover

Unit: mm

A&D Company, Limited
3-23-14 Higashi-Ikebukuro, Toshima-ku, Tokyo 170-0013 JAPAN
Telephone:[81](3)5391-6132 Fax:[81](3)5391 6148
http://www.aandd.jp

A&D ENGINEERING, INC.
1756 Automation Parkway, San Jose, CA 95131 U.S.A.
Telephone:[1](408)263-5333 Fax:[1](408)263-0119

A&D MERCURY PTY. LTD.
32 Dew Street, Thebarton, South Australia 5031 AUSTRALIA
Telephone:[61](8)8301-8100 Fax:[61](8)8352-7409

A&D KOREA Limited
Manhattan Bldg. 8F, 36-2 Yoido-dong, Youngdeungpo-gu, Seoul, KOREA
Telephone:[82](2)780-4101 Fax:[82](2)782-4280

A&D INSTRUMENTS LTD.
Unit 24/26 Blacklands Way Abington Business Park,
Abington, Oxon OX14 1DY United Kingdom
Telephone:[44](1235)550420 Fax:[44](1235)550485
<German Sales Office>
Große Straße 13 b 22926 Ahrensburg Germany
Telephone:[49](0)4102 459230 Fax:[49](0)4102 459231

A&D RUS CO., LTD.
Vereyskaya str.112 Kuntsevo Block, 121357, Moscow, RUSSIA
Telephone: [7] (495) 937-33-44 Fax: [7] (495) 937-55-66

A&D INSTRUMENTS INDIA PRIVATE LIMITED
509 Udyog Vihar Phase V, Gurgaon-122 016, Haryana, INDIA
Telephone: [91](124) 471-5555 Fax: [91](124) 471-5599


SV-A Series-ADCH-01-TP1-09602