SHIMADZU
Excellence in Science

C228-E008

Constant Test Force Extrusion Type Capillary Rheometer Flowtester

CFT-EX Series

Evaluation of Fluidity and Thermal Properties

The CFT-EX series is ideal for research and development, production process and quality control of thermoplastic resins, thermosetting resins, toners, composites, rubbers, and other flowable materials.

CFT-EX Series

Constant Test Force Extrusion Type Capillary Rheometer Flowtester

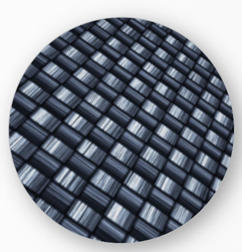
- Efficient testing with a reliable evaluation method
- Natural, easy test flow
- Supported by more than 50 years of technology and know-how

Thermoplastic Resins

Copying Machine Toners

Rubber Materials

Thermosetting Resins and Adhesives



Composites

Ceramic Materials

*The photo is an example of a combination with desktop PC display of the touch panel type.

Efficient Testing with a Reliable Evaluation Method

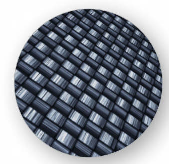
High test force precision, provided by a weight-based constant test force loading system, enables high measurement reproducibility and test efficiency. In addition to increased operability to improve testing efficiency, accurate temperature measurement and stable control are provided through a reliable temperature control system.

Evaluation of Softening and Flow Beginning Temperature Using Constant Heating Rate Testing

Testing methods include a constant temperature method a constant heating rate method. The constant heating rate method permits measurement of resin softening temperature and flow beginning temperature to determine shear rate and viscosity at each temperature and cannot be conducted using other capillary type rheometers.

Viscosity Evaluation of Thermosetting Resin

Weight-based constant test force extrusion is used to measure the amount of piston movement (movement speed), which is used to determine viscosity. Highly reproducible measurements of fluidity of thermosetting resins, which cure rapidly due to heating, can be determined due to the highly precise temperature control and the range of test forces available.



Improved Efficiency

Enhanced labor-savings have been implemented throughout the entire testing process, from setting of the sample and starting the test to output of the test results. All of this greatly increases the efficiency of production procession, quality control, and research and development testing.

Setting the Sample

· Selecting test conditions causes the cylinder temperature to rise to the set temperature.

· The bending press joint (tip of the loading unit) facilitates setting the sample.

Test Start

· The test starts automatically by pressing the start button.

· A stable test force is achieved using the loading weights.

· The test continues until extrusion is complete.

· A cylinder cover ensures that testing is conducted safely.

Output of Test Results

· Temperature and test status can be monitored in real time.

· Test results are quickly output as a report.

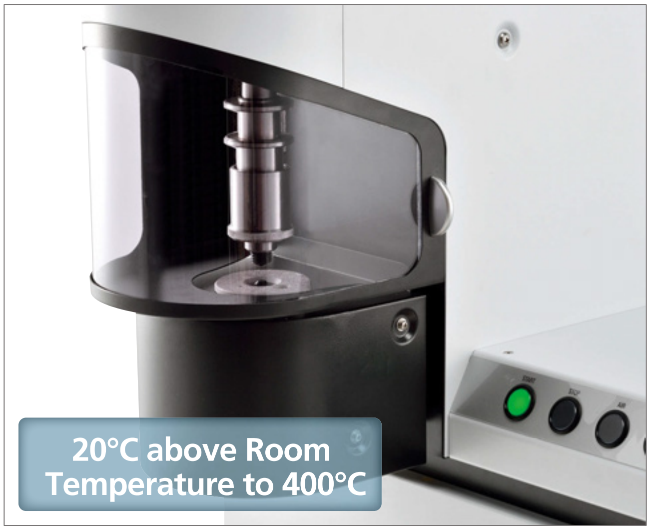
· Use of analysis software permits detailed analysis and graph generation.

A Combination of Safety and Functionality

● High Test Force Precision and Wide Pressure Range up to 50 MPa

High test force precision is obtained by the weight-based fixed test force loading system. In addition, since the test force can be set over a wide range, measurement can be conducted using a pressure that is close to actual injection molding conditions. Under high pressure, which cannot be obtained using the melt flowrate (MFR) measurement method (up to 21.6 kg/about 2 MPa), data that is useful for molding can be obtained.

● Wide Test Temperature Range from 20°C above Room Temperature to 400°C

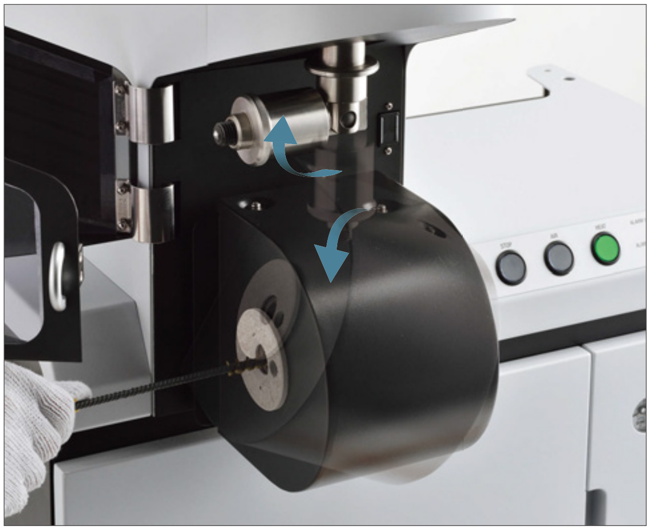


The wide temperature range makes it possible to measure a wide range of materials, including engineering plastics. Furthermore, by using the optional low-temperature test attachment and high-temperature heating attachment, the applicable temperature range can be expanded.

● High-Precision Temperature Control System

The temperature control system developed specifically for the flowtester provides accurate measurement and stable control of the temperature, which is one of the most important qualities of a capillary rheometer.

● Focus on Ease of Use and Safety



Since the furnace can be rotated up to 90° to the left and right, little effort is required for die replacement and furnace cleaning. In addition, a safety cover prevents inadvertent contact with the furnace and piston during testing

Natural, Easy Test Flow

The software, which is configured to match the operation flow, offers a smooth progression through setting of conditions, starting and stopping the test, data acquisition, data storage, and reanalysis of stored data.

Setting Up Test Conditions to Storing Data - All on a Single Window

All operations associated with selecting the test method (either constant temperature or constant heating rate method), setting of test conditions, and output from test start to test results can be accomplished effortlessly. Data is automatically saved, and can be re-analyzed at any time after the test using off-line software.

From entering analysis conditions to displaying results, user operations can be conducted smoothly on a single window. The status of the instrument is displayed at the top of the window to permit verification of the test status at all times. In addition, the buttons used for conducting operations are arranged as easily recognizable icons, making this window easily understandable, even to first-time users. Lastly, saving and retrieving condition settings is possible, which facilitates smooth routine inspections.

Higher Level Evaluation Using a Variety of Analysis Methods

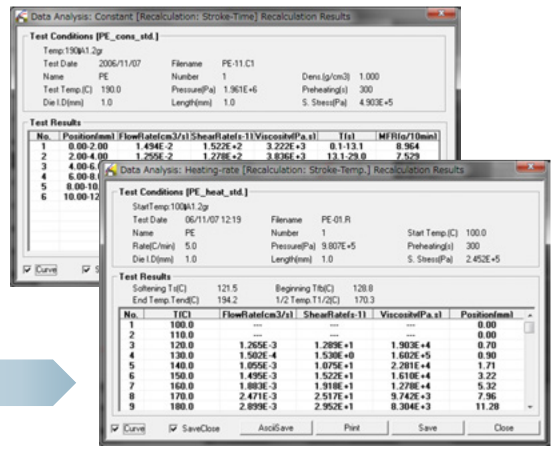
Along with enhanced analysis functions, many graph generation and overlay functions as well as a zoom feature are included. Bagley viscosity correction and calculation of shear sensitivity (shear stress/shear rate) allows estimation of molecular weight distribution.

Reanalysis of Test Data

After setting a calculation interval based on the stroke or time (temperature), the viscosity/shear rate can be determined for that interval. The graph can accommodate up to ten overlaid files, and the pointer can be used to zoom in on any designated region of the graph.

Constant Temperature Method

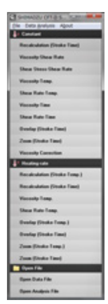
Constant Heating Rate Method

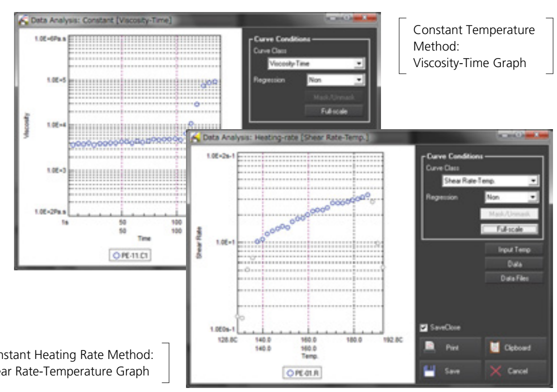


Create a Variety of Graphs for More Detailed Data Analysis

Display stored test data files, and automatically create graphs by selecting the graph menu.

Graph Menu



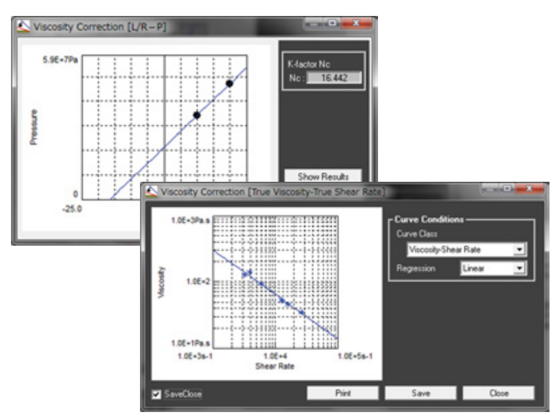


Constant Temperature Method: Viscosity-Time Graph

Constant Heating Rate Method: Shear Rate-Temperature Graph

Advanced Analysis Using Viscosity Correction

Shear stress, shear rate and viscosity measured by a capillary rheometer are calculated by ignoring the pressure loss that occurs at the exit and entrance of the die. With the CFT, it is possible to obtain more accurate data using the Bagley viscosity correction plot (a tube length correction method which assumes that the die length has been extended for pressure correction).



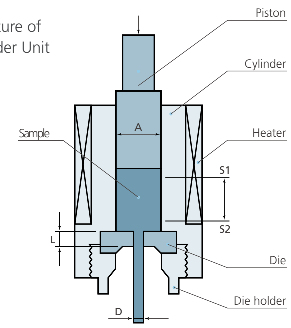
Supported by More Than 50 Years of Technology and Know-How

For more than 50 years, the CFT series has been used in research and development, production process and quality management of various types of flowable materials, including thermoplastic resins, thermosetting resins, toners and rubbers. Various applications are supported and extensive evaluations and analyses are offered to meet the requirements of users.

Principle

A flowtester is a capillary rheometer that is used to measure the viscosity resistance that occurs when a melted sample flows through a capillary tube. The measurement component has a structure like that shown in the figure. The sample is introduced into the cylinder, melted by application of heat and then subjected to a constant pressure applied by a piston positioned above the sample. The melted sample is extruded through a narrow orifice in a die. Its flow rate is determined from the speed of the piston at that time, and the sample fluidity, referred to as melt viscosity, is calculated.

Structure of Cylinder Unit



(1) Flow rate Q

$$Q=A\cdot\frac{S_2-S_1}{10\cdot\triangle t}\ (\mathrm{cm^3/s})$$

Where, A :Piston cross sectional area (cm^2)
S1 :Calculation start point (mm)
S2 :Calculation end point (mm)
$\triangle$t:Piston travel time from start point to end point (second)

(2) Apparent shear rate γ

$$\gamma=\frac{32Q}{\pi D^3}\cdot 10^3(\mathrm{s^{-1}})$$

Where, D:Die orifice diameter (mm)

(3) Apparent shear stress τ

$$\tau=\frac{PD}{4L}\ (\mathrm{Pa})$$

Where, P:Test pressure (Pa)
L:Die length (mm)

(4) Apparent viscosity η

$$\eta=\frac{\tau}{\gamma}=\frac{\pi D^4 P}{128LQ}\times 10^{-3}(\mathrm{Pa\cdot s})$$

JIS K7210 (Appendix Flow test method for plastics)

The flow rate is defined in the Japanese Industrial Standards (JIS) by the following equation. When using the CFT-EX series flowtester, the flow rate data are consistent with those given by the JIS method when the calculation start point is set to 3 mm and the calculation end point to 7 mm.

$$\text{Flow rate value Q}=\frac{0.4}{t}$$

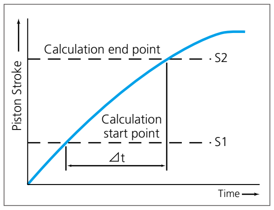
t: Time (second) for the piston to travel from the 3 mm point to the 7 mm point

Selection of Measurement Method According to Material

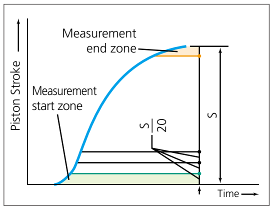
Two measurement methods have been adopted. The appropriate method can be selected depending on the material.

Constant Temperature Method

In the testing method based on the use of a constant temperature, two calculation points on the piston's descent are set beforehand. The calculation is conducted using either the limiting method or the automatic method. In the limiting method, the flow rate is determined from the stroke-time curve of the piston between the above two points. In the automatic method, the stroke-time curve is divided into 20 segments, and the flow rate is determined from the gradients of the curves of those segments except for the first and last segment, with the maximum value taken automatically as the flow rate.



Limiting Method

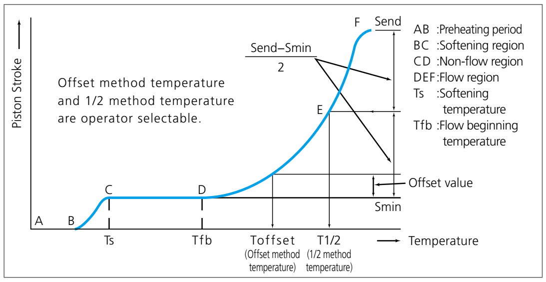


Automatic Method

Constant Heating Rate Method

With this method, a sample is extruded while the temperature is increased at a constant rate. This method is unique to this flowtester and cannot be conducted with other capillary rheometers.

The advantage of this instrument is that it can measure the fluidity characteristics of a sample over a wide temperature range from its solid phase to its flow phase in a single measurement. In this measurement, the sample's softening temperature and its flow beginning temperature can be determined both easily and accurately, permitting rapid determination of the fluidity at the respective temperatures in a single test run.



Flow Curve Using Constant Heating Rate Method

Achievements in Many Industries

● Thermoplastic Resins

Measurement of the melt viscosity of resins facilitates the selection of measurement conditions, such as temperature, pressure and flow rate during molding. The CFT-EX series, which supports measurement at shear stresses similar to those used under actual molding conditions, provides very useful data.

● Thermosetting Resins and Adhesives

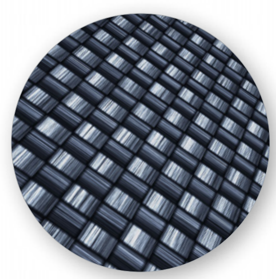
Measurement of the curing rate of thermosetting resins is difficult using typical physical methods. The CFT-EX series, on the other hand, permits measurement of the curing time from a flow curve.

● Copying Machine Toners

Melting temperature and viscosity of toner are key factors to obtaining clear print with copying machines. The CFT-EX series permits simple and efficient measurement of such temperature and viscosity.

● Composite Materials

Paying close attention to viscosity is critical when conducting press and injection molding of composite materials such as GFRP and CFRP, consisting of reinforced fibers mixed with thermoplastic and thermosetting resins, respectively. The viscosity can be evaluated under various pressure and temperature conditions for injection molding, as well as the matrix (base material) and filler content.



● Rubber Materials

Injection molding machines are typically used in the molding of rubber. Since the mechanism of the CFT-EX series is similar to that used in injection molding machines, very useful data can be obtained, thereby permitting, for example, management of viscosity in unvulcanized rubber.

● Ceramic Materials

In the molding of ceramics, resin additives referred to as binders are typically added to the mold to improve fluidity. This fluidity can be measured to determine the optimal proportion of binder to be used.

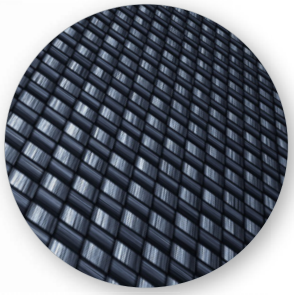
● Other Applications

Foods: Evaluation of compositions of chewing gum, butter, margarine, bread, candy, chocolate, etc. for determining optimal consistencies in the mouth
Paints and Inks: Evaluation of writing characteristics and fluidity of ink used in ballpoint pens and fountain pens, etc.
Fibers: Selection of melt spinning production conditions

Viscosity Evaluation of Thermoplastic Resins (GFRP)

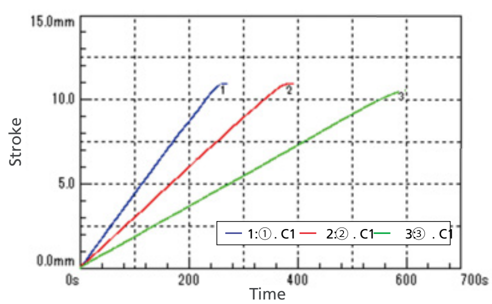
Constant

Most mass produced molded plastic products are injection-molded. The appropriate temperature and pressure for injection molding differs depending on the type of resin and shape of the die, where poor molding parameters could cause over-filling, under-filling, sink marks, voids, or other molding defects. Even if appropriate molding parameters are used, any changes in the status of the resin raw materials used could cause molding defects. Therefore, it is important to control the quality of resin raw materials on a daily basis.
Furthermore, it is important to perform the daily resin raw material control measurements under high-pressure conditions that approximate molding conditions, which is not possible using the melt flow rate measurement method.



Viscosity Evaluation Using Constant Temperature Method

Polycarbonate (PC) samples of various molecular weights containing 33 % glass fiber (GF) were measured using the constant temperature method. The flow curves clearly show that the higher the molecular weight, the higher the sample's viscosity.



Flow Curves: Stroke-Time Graph

Measurement Conditions

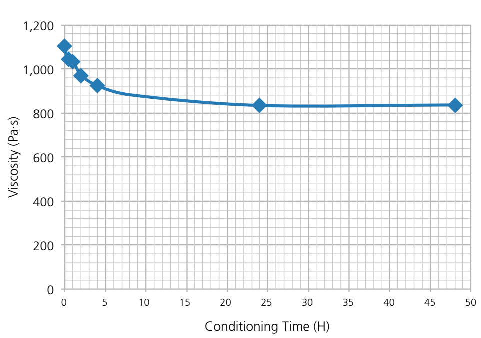
Test Method	Constant temperature test
Die Diameter	1 mm
Die Length	10 mm
Test Temperature	280°C
Test Pressure	1.96 MPa
Preheating Time	300 sec
Sample Size	1.5 g

Measurement Results

Sample No.	Component	Molecular Weight	GF Ratio	Shear Rate (s^{-1})	Viscosity (Pa·s)
①	PC/SGF	17000	33%	44.7	1,098
②	PC/SGF	22000	33%	30.6	1,604
③	PC/SGF	26000	33%	18.5	2,657

Changes in Viscosity Due to Moisture Absorption Time

The change in resin viscosity due to moisture absorption was measured using sample (1), with a molecular weight of 17,000. After drying for 13 hours in a vacuum environment at 100 °C, the sample was left in a room with a temperature of about 23 °C and about 50 % relative humidity for constant temperature testing.
The graph shows that the fluidity increases and viscosity decreases as more moisture is absorbed. The results show that after about four hours of conditioning, viscosity drops sharply and then almost stops decreasing after about 24 hours.
Due to the large changes in resin viscosity that result from moisture absorption, using resin materials that have not been controlled for moisture can result in injection molding failures. Therefore, such injection molding problems can be avoided by using a CFT-EX series flowtester to measure the viscosity to ensure that it is within given standards before molding the parts.



Changes in Viscosity Due to Moisture Absorption

Measurement Results

Conditioning Time (H)	Shear Rate (s^{-1})	Viscosity (Pa·s)
0	44.38	1,105
0.25	46.84	1,047
0.5	47.35	1,036
1	47.38	1,035
2	50.41	973
4	53.03	925
8	55.54	883
24	58.77	834
48	58.61	837

Evaluation of Thermosetting Resins (Epoxies)

Heating

When thermosetting resins are heated, they melt and are able to flow, but further heating increases viscosity and causes curing. The minimum viscosity value, the time it takes to reach that minimum, and the time it takes for curing depend on the temperature used to melt the resin. Unless these viscosity and time values are appropriate for the molding process, they can result in molding defects. For resins, characteristic values can vary between lots or due to other factors. Therefore, controlling the resin viscosity is very important to ensure that the characteristic values do not vary and good products are produced.

Measurement of the Minimum Melt Viscosity Value

The fluidity properties of thermosetting resins are often measured using constant temperature testing. Unlike thermoplastic resins, the thermoset viscosity is constantly changing. Therefore, the minimum melt viscosity value can be determined automatically by using automatic constant temperature testing.

In this case, three types of thermosetting resins were tested using the constant temperature method. The testing pressure was selected so that the sample would melt and flow and then stop flowing due to curing.

The viscosity-time graph, which shows the change in viscosity over time, indicates that the sample melts and starts to flow after about 3 seconds, reaches its minimum viscosity after about 10 seconds, and then stops flowing after about 18 seconds.

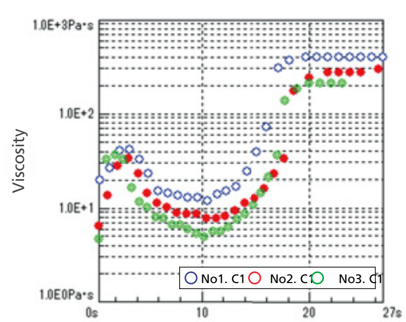
The CFT calculates viscosity by measuring the amount of piston movement (movement speed) during constant test force extrusion. Therefore, even when the sample cures due to heating, the piston displacement merely stops, which has no effect on controlling the test force. Consequently, it provides extremely stable and highly reproducible test data.

Measurement Conditions

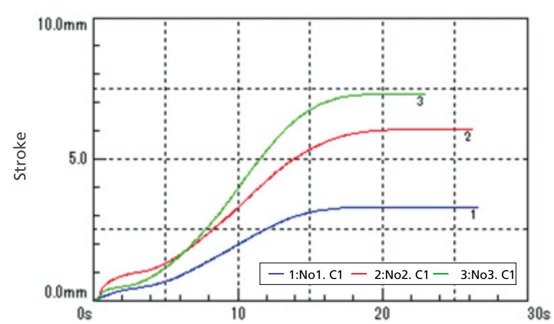
Test Method	Constant temperature test
Die Diameter	0.5 mm
Die Length	10 mm
Test Temperature	185°C
Test Pressure	2.45 MPa
Preheating Time	15 sec
Sample Size	2.5 g (formed into pellets)

Measurement Results

Sample No.	Shear Rate (s^{-1})	Viscosity (Pa·s)
1	2,471	12.4
2	4,073	7.5
3	5,810	5.3



Viscosity-Time Graph



Stroke-Time Graph

A Split Nozzle Makes Cleaning Easy

Due to the relatively low minimum melt viscosity and high fluidity of thermosetting resins, long nozzles with small hole diameters are often used. Therefore, it can be difficult to remove the residual resin inside the nozzle once the resin has cured after measurements.
However, using a split nozzle, which splits into two halves down its center, allows easy removal of the resin, thereby enabling more efficient cleaning and measuring.

Evaluation of the Temperature Characteristics of Toner

Heating

During laser printing, toner powder, which has a particle diameter of about 5 µm, is transferred onto copy paper and heated so that it adheres to the paper. In the case of color laser printing, this process is repeated for four different colors. If the melting temperature and melt viscosity differ for the four colors, then it could cause bleeding or poor adhesion in areas printed first and reduce print quality. To prevent that, the temperature characteristics associated with toner flow must be the same for all four colors.

Flow Beginning Temperature and 1/2 Method Temperature for Four Toner Colors by Constant Heating Rate Testing

The constant heating rate test was performed for all four color toners used in the same color printer (cyan, magenta, yellow, and black).
The constant heating rate method was used to calculate characteristic values, such as the softening temperature, flow beginning temperature, 1/2 method temperature, and offset temperature.

1/2 method temperature	: Midpoint between flow beginning and flow ending temperatures
Offset temperature	: Temperature at flow beginning stroke plus any arbitrary offset stroke

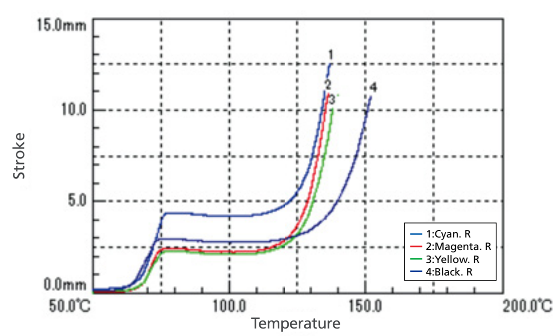
Test Conditions

Test Method	Constant heating rate test
Die Diameter	0.5 mm
Die Length	1 mm
Beginning Temperature	50°C
Ending Temperature	200°C
Heating Rate	5°C/min
Test Pressure	0.98 MPa
Preheating Time	240 sec
Sample Size	1 g (formed into pellets)

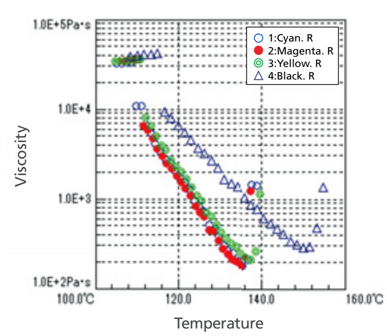
All four toner colors have very similar characteristic values. In particular, the values for the three non-black colors were almost identical.
Ensuring that the respective temperature and fluidity characteristics are approximately the same is important for maintaining the print quality of color laser printers. Therefore, CFT-EX series flowtesters serve an important role in toner research and development, and quality control applications.

Test Results

Sample Name	Softening Temperature (°C)	Flow Beginning Temperature (°C)	1/2 Method Temperature (°C)	1/2 Method Viscosity (Pa·s)
Cyan	76.8	105.1	132.5	248.2
Magenta	75.4	105.8	131.8	240.7
Yellow	76.3	104.8	133.5	285.8
Black	73.8	108.5	145.9	402.4



Stroke-Temperature Graph



Viscosity-Temperature Graph

Press-Forming Powdered Samples for Efficient Measurement

Due to the small size of toner particles, samples could easily scatter if placed directly in the sample chamber or spill out from die orifices. Therefore, for samples such as these, a hand press and preforming die unit can be used to press them into a form that can be more easily placed in the sample chamber. Accurate values can be measured efficiently by placing only one pellet in the chamber.
For thermosetting resin samples, measurements can fail due to ongoing curing during the time it takes to place samples in the sample chamber. Therefore, it is extremely important to pelletize samples before measurement.

Fluidity Evaluation of Unvulcanized Rubber (Rubber Compounds)

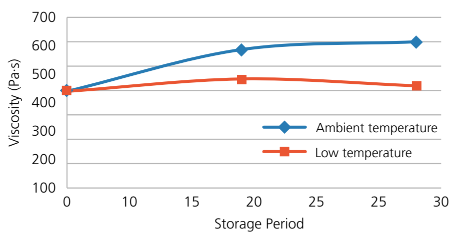
Constant

Rubber products are produced by forming rubber compounds (mixtures of rubber and additives that provide specific functional characteristics) in a mold and then applying heat. Therefore, the fluidity of rubber compounds can have a major effect on molding quality. Unformed rubber compounds change their characteristics after long storage periods, which can cause fluidity to deteriorate or the molding process to fail, depending on how they are stored.

In this case, a rubber compound was stored at ambient temperature and low temperature for 14 days and 28 days immediately after kneading and then the fluidity was evaluated. The results showed that the given sample could be stored at low temperatures without a significant change in fluidity, even after one month. Using the CFT-EX series allows evaluation of the rubber compounds storage temperatures and storage periods without actually having to mold any parts.

Test Conditions

Test Method	Constant temperature test
Die Diameter	0.5 mm
Die Length	1 mm
Test Temperature	280°C
Test Pressure	20.1 MPa
Preheating Time	0 sec
Sample Size	1.6 g



Changes in Viscosity Due to Storage Methods

Test Results

Storage Temperature	Storage Period	Viscosity (Pa·s)
Ambient Temperature	0	395.7
	14	568.1
	28	600.0
Low Temperature	0	395.7
	14	447.5
	28	419.3

Evaluation of the Temperature Characteristics of General Purpose Plastics

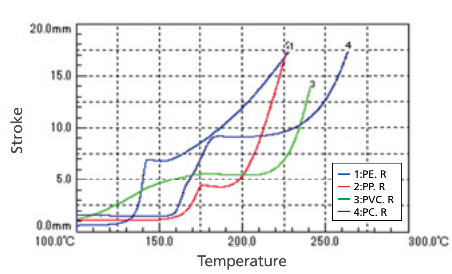
Heating

Determining the temperature where thermoplastic resins start softening and flowing, and measuring their fluidity properties are extremely important for evaluating the properties of thermoplastic resins.

The stroke-temperature graph shows that the sample starts flowing after it exceeds the flow beginning temperature and decreases in viscosity as the temperature increases (graph slope increases). The viscosity can be calculated for each temperature after initial flow. To accurately determine the viscosity at each temperature, the constant temperature method is recommended.

Test Conditions

Test Method	Constant heating rate test
Die Diameter	1 mm
Die Length	1 mm
Beginning Temperature	100°C
Ending Temperature	300°C
Heating Rate	5°C/min
Test Pressure	0.98 MPa
Preheating Time	300 sec
Sample Size	1.2 g



Stroke-Temperature Graph

Test Results

Sample Name	Softening Temperature (°C)	Flow Beginning Temperature (°C)	1/2 Method Temperature (°C)	1/2 Method Viscosity (Pa·s)
Polyethylene	142.4	153.6	203.6	16,370
Polypropylene	175.6	187.2	215.6	5,716
Polyvinyl chloride	175.3	208.2	234.4	6,138
Polycarbonate	183.1	205.1	253.9	10,590

Cylinder Cooling Fan Improves Cycle Time for Constant Heating Rate Tests

Constant heating rate test measurements start at a low and finish at a high temperature. The cylinder cooling fan can be quickly attached to the bottom of the furnace to force-cool the cylinder, which can significantly shorten the cooling time.
A piston for force-cooling the cylinder with compressed air is also available.

Specifications and System Configuration

Specifications

Model		CFT-500EX	CFT-100EX
Pressurizing Method		Constant test force extrusion using weights	
Extruding Pressure	Range	0.4903 to 49.03 MPa (0.493 MPa step selection)	0.098 to 9.807 MPa (0.098 MPa step selection)
	Precision	Within ±1% of the set value	
Test Method		Constant temperature method and constant heating rate method	
Measuring Range		1×10^{1} to 1×10^{6} Pa·s	2.5×10^{0} to 2.5×10^{5} Pa·s
Heating Method		Electric, 500 W	
Temperature	Operation Range	20°C above room temperature to 400°C	
	Heat Sensor	Platinum resistance temperature sensor	
	Measuring Precision	±0.3 °C + error of heat sensor (± (0.3 + 0.005 ltl) °C) Note: ltl is the absolute value of the measured temperature.	
	Control Precision	±0.2 °C (in stable state)	
	Heating Rate	0.5 to 6.0°C/min (for constant heating rate method), min. 0.1°C step	
Piston Stroke	Effective Stroke	15 mm	
	Detector	Linear potentiometer	
	Measuring Precision	±0.5 % (for 15 mm stroke)	
	Resolution	0.01 mm	
Sample Size		Max. 1.5 cm^3	
Piston Diameter		11.282 mm (area1 cm^2)	
Cylinder Diameter		11.329 mm	
Die		Die orifice 1 mm × 1 mm length	
Operational Requirements	Power Supply	100 V AC, 50 or 60 Hz, max. 700 VA (Step-down transformer is required separately)	
	Pneumatic Supply	Approx. 0.4 MPa, 15 NL/cycle (Flow rate required per test) Note: Please provide a connection that can be connected to a rubber hose with 9.5 mm I.D. (18.5 mm O.D.) included for connecting a compressed air supply.	
	Temperature	10 to 35 °C	
	Humidity	60% max. (no condensation)	
Dimensions and Weight	Main Unit	W690 mm × D640 mm × H1540 mm 160kg	
Control Computer	Compatible Operating Software	Windows 8.1 ,Windows 7 (32bit/64bit)	
	Communication Interface	USB 2.0, 1 port	
	Display	1280 × 1024 or higher resolution recommended	

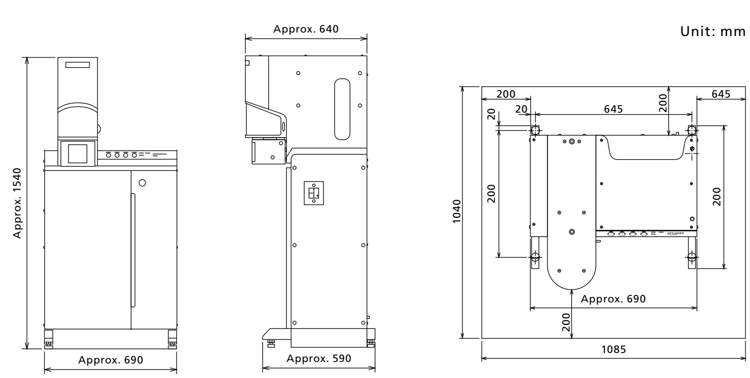
System Configuration

			CFT-500EX	CFT-100EX
Main Testing Unit			1 unit	1 unit
Piston	1 cm^2	347-25000-01	1 pc	1 pc
Die	1.0 mm I.D. 1.0 mm Length	341-69057-12	1 pc	1 pc
Weights	5 kg	347-25909-01	9 pcs	3 pcs
	2 kg	341-00014-01	1 pc	1 pc
	1 kg	341-00013-01	2 pcs	2 pcs
	0.5 kg	341-00012-01	1 pc	—
	0.2 kg	341-00134-01	—	4 pcs
Die Holder		341-69878	1 pc	1 pc
Die Orifice Stopper		341-69883	1 pc	1 pc
Wire Brush		339-89172	1 pc	1 pc

Installation Example

Portable Computer Included

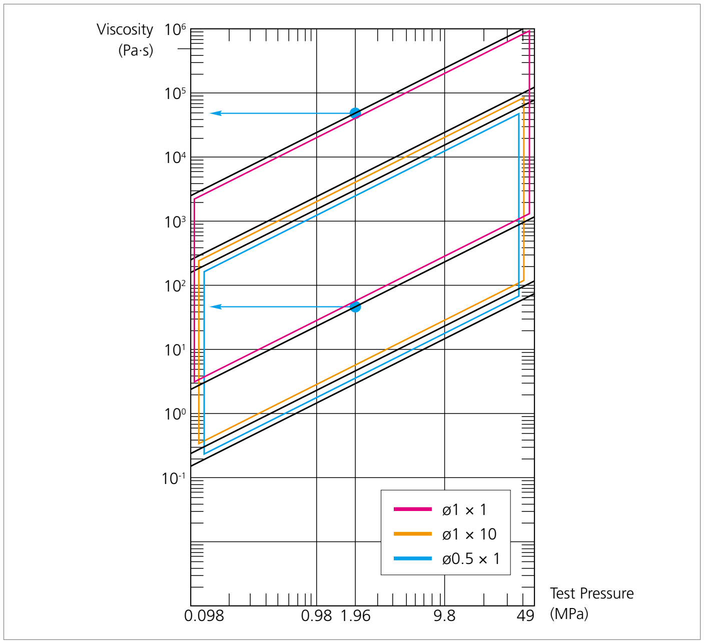
Dimensions



Options

Optional Additional Dies (Nozzles)

Die Orifice I.D. × Length (mm)	Shape and Material	P/N
0.3 × 1.0	Flat (high speed tool steel: SKH material)	341-69057-02
0.5 × 0.5		341-69057-03
0.5 × 1.0		341-69057-04
0.5 × 2.0		341-69057-06
0.5 × 2.5		341-69057-07
1.0 × 1.0 (Included as standard)		341-69057-12
1.0 × 2.0		341-69057-13
0.3 × 1.0	Flat (stainless steel)	341-69057-22
0.5 × 0.5		341-69057-23
0.5 × 1.0		341-69057-24
0.5 × 1.5		341-69057-25
0.5 × 2.0		341-69057-26
0.5 × 2.5		341-69057-27
0.5 × 5.0		341-69057-28
0.5 × 10.0		341-69057-29
1.0 × 5.0		341-69057-34
1.0 × 10.0		341-69057-35
2.0 × 2.0		341-69057-15
2.0 × 5.0		341-69057-17
2.0 × 10.0		341-69057-18
3.0 × 3.0		341-69057-43
3.0 × 6.0		341-69057-45
2.095 × 8.0		341-69057-51
No orifice		341-69057-52
0.5 × 10.0	Split type nozzle (ultra-hard alloy)	341-68997-07
1.0 × 10.0		341-68997
0.5 × 10.0	Split type nozzle (stainless steel)	341-68997-02
1.0 × 10.0		341-68997-01
—	Split type nozzle disassembly tool	341-69024



Reading the Graph

Given a die with a 1 mm diameter and 1 mm long orifice, for example, and a test pressure of 1.96 MPa selected, then viscosities from 50 to 50,000 Pa·s can be measured.
If the orifice length is 5 mm, then viscosity values would be 1/5 those above.

Test Temperature and Pressure Range Extension Options

- **Low Temperature Test Attachment**
  (P/N 344-04024-11, 50 Hz; 344-04024-12, 60 Hz (with a transformer))
  Used for testing at low temperatures.
  Temperature range: 0 to +90°C
  CHW-1 heating attachment included

- **High Temperature Heating Attachment with a Piston (1 cm2)**
  (P/N 344-81960-01)
  Used for testing at high temperatures.
  Temperature range:
  20°C above room temperature to 500°C

- **Large Sample Heating Attachment**
  (P/N 347-25001-11)
  This heating attachment cylinder has a large cross-sectional area to decrease the test pressure to 1/4 of the regular level.
  Model: CH-4P
  Cylinder cross sectional area: 4 cm^2
  Breakdown: Large heating attachment
  Piston 4 cm^2

Cylinder Cooling Options (Cool the cylinder with forced air to improve efficiency of constant heating rate tests)

- **Cylinder Cooling Fan** (P/N 347-26025)
  Cylinders must be cooled rapidly after constant heating rate tests to prepare for the next test. The cooling fan attaches to the bottom of the heating attachment to directly cool the heating attachment.
  Note: Cannot be used with low-temperature test attachments.

- **Cylinder Cooling Piston** (P/N 341-69997-02)
  Cylinders must be cooled rapidly after constant heating rate tests to prepare for the next test. This piston blows air on the cylinder to enable rapid cooling.
  Breakdown: Cylinder cooling piston and air hose
  Note: Cannot be used with large sample heating attachments.

Sampling Options

- **Preforming Die Unit and Hand Press** (P/N 347-25008-01)
  Powdered samples can be difficult to insert in the cylinder. Molding the samples in advance can make insertion easier.
  Breakdown: · Preforming die unit (P/N 347-25009-01)
  Solid sample dimensions: Approx. I.D.11 × L13 mm
  · Hand press (P/N 347-25011)
  Press force: Max. approx. 1200 N

- **Electronic Balance**
  Used to measure sample mass

Utility Options

- **Air Compressor** (P/N 042-70040-01)
  Provide for sites without a compressed air supply.
  1. Rated pressure 0.5 MPa
  2. Discharge air volume 50 Hz: 20 L/min, 60 Hz: 24 L/min
  3. Tank capacity 30 L

Testing and Evaluation Machines

Precision Universal Tester
AG-Xplus Series

High-Speed Tensile Testing Machine
Hydroshot HITS Series

Dynamic Ultra Micro Hardness Tester
DUH Series

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