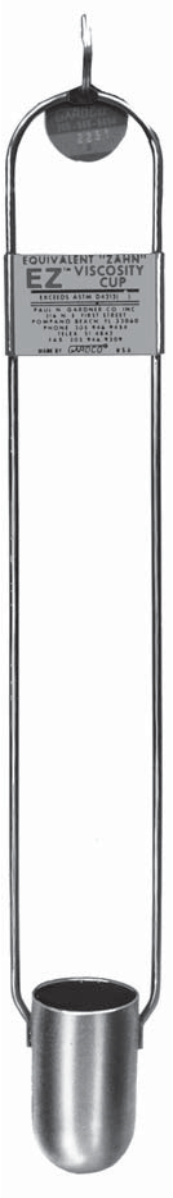
GARDCO® PAUL N. GARDNER

A BYK Instrument Company

EZ™/Zahn Dip Viscosity Cup

Instruction Manual

Calibrated Viscosity Cups Designed, Produced & Sold by Paul N. Gardner



- ☐ **Parlin Viscosity Cup**
- ☐ **Standard Ford Viscosity Cup**
- ☐ **I.S.O. Viscosity Cup**
- ☐ **Din Viscosity Cup**
- ☐ **Fisher Standard Cup**
- ☐ **Standard Ford Dip Viscosity Cup**
- ☐ **Mini Ford Dip Viscosity Cup**
- ☐ **Mini I.S.O. Dip Viscosity Cup**
- ☐ **Mini Din Dip Viscosity Cup**
- ☐ **Fisher Dip Viscosity Cup**
- ■ **EZ™ ZAHN (ASTM) Dip Viscosity Cup**
- ☐ **S-90 ZAHN Signature Dip Viscosity Cup**

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A member of ALTANA

CALIBRATED EZ™ ZAHN (ASTM) DIP VISCOSITY CUP SERIES

3% GUARANTEED TOLERANCE
COMPLIES WITH & EXCEEDS ASTM D4212

- Oils used to standardize EZ™ Cups are produced and ISO certified Quality Management System, comply with the requirements and guidance of ISO 17034 and quality control is done from an ISO/IEC 17025 accredited laboratory.
- The EZ™ Cup formula for each cup of the series matches the applicable ASTM formula in D4212 at the recommended calibration level.
- EZ™ Cups are compatible to ASTM D1084 Viscosity of Adhesives and ASTM D816.
- Conversion table relating efflux time in seconds, to the nearest tenth of a second, to viscosity in centistokes furnished with each EZ™ Cup.
- EZ™ Cup calibration is traceable to the National Institute of Standards and Technology.
- Calibration and Certification procedures qualify under ISO/IEC 17025 as applicable.
- The EZ™ Cup is not matched by any other cup of its type, either with respect to the advantages listed above, in highest quality of workmanship or in continuing quality control procedures.
- All stainless steel cup and handle.
- **THE FINEST, MOST RELIABLE, CALIBRATED & DOCUMENTED CUP ON THE MARKET!**

Additional EZ™ Cup Advantages

- The EZ™ Cup orifices are machined rather than drilled to ensure exact centering in the cup hemisphere base and a minimum of burr formation. This ensures an orifice of specified length and a correct symmetrical efflux stream.
- The EZ™ Cup support rods are offset from the side of the cup and secured to the cup sidewall below the cup rim. This eliminates errors due to test material drainage from support surfaces.
- The increased separation width of the support rods by over 20% and the lowering of weld to the cup provide best possible conditions for cleaning.

DEVELOPED AND MANUFACTURED BY PAUL N. GARDNER (GARDCO®) EZ™ is a Registered Trademark of Paul N. Gardner

VISCOSITY

The EZ™ Viscosity Cup Series is a logical and necessary outgrowth of the standardization studies on the Zahn Signature and similar cups for the promotion of this most popular type of viscosity measuring instrument as a national and international standard. Not only has this cup been improved with respect to earlier produced cups and designed to comply to the requirements of ASTM D4212 but, in addition, each EZ™ Cup is furnished with a table which permits conversion between efflux time in seconds to the nearest tenth of a second to viscosity in centistokes. This table is particularly useful in determining efflux time in seconds when viscosity in centistokes is known.

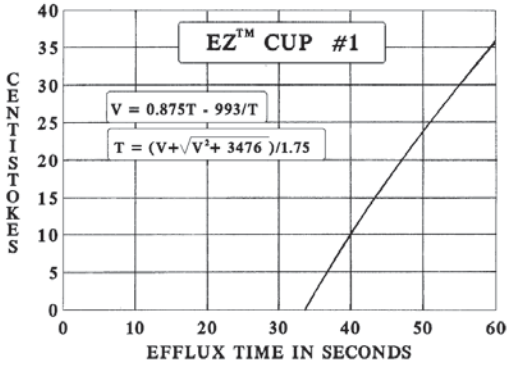
For those users who require documented certification of their measuring equipment, the EZ™ cups may be ordered, at an additional charge, with a CERTIFICATE of CALIBRATION. This document contains not only information on actual cup calibration with standard oils traceable to the National Institute of Standards and Technology but in addition, this certification also complies to conditions and procedures under the requirements of ANSI/ NCSL Z540 or ISO/IEC 17025.

The EZ™ cups are produced to very close mechanical tolerance in elaborate jigs and fixtures. Such equipment not only ensures that each cup is correctly produced but also that all cups are identical. All parts of the cup are of stainless steel except for the name plate. The following table provides operating range specifications, cup midrange sensitivity and recommended calibrating oils. Following this table are graphs and mathematical formulas that relate efflux time in seconds to centistoke viscosity.

SPECIFICATION TABLE

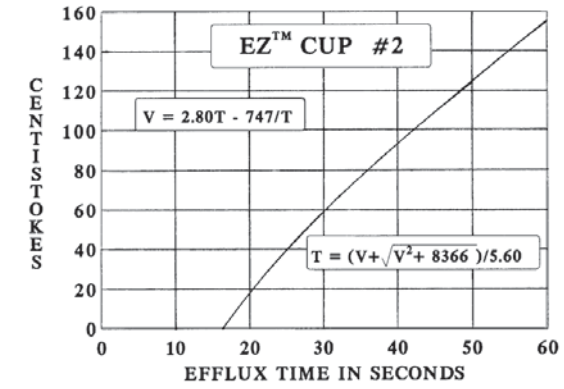
Cup Number	Seconds Range	Centistoke Range	Midrange Sensitivity (**)	Calibration Oil Number/ Centistokes (*)
1	40 TO 60	10 TO 36	1.3	G-10/19
2	20 TO 60	19 TO 156	3.3	G-60/117
3	12 TO 60	64 TO 596	10.5	G-200/458
4	10 TO 60	79 TO 784	13.9	G-200/458
5	10 TO 60	161 TO 1401	24.2	G-350/878

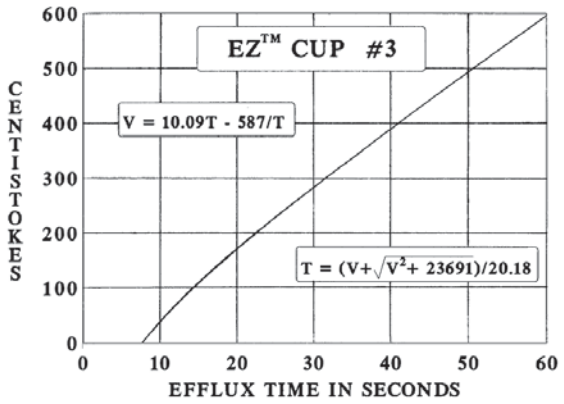
(*) CENTISTOKE VALUES ARE NOMINAL - ACTUAL VALUES PRINTED ON LABELS
(**) STATED AS CENTISTOKES PER SECOND OF EFFLUX TIME

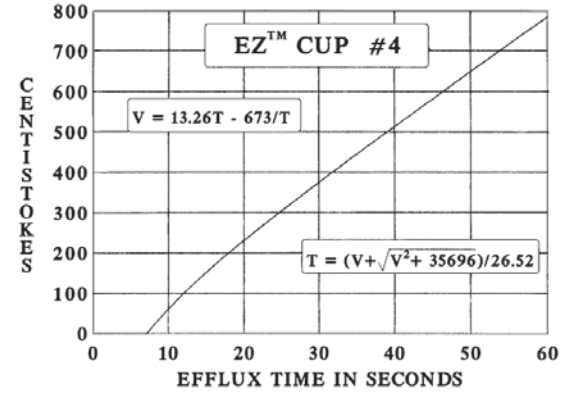


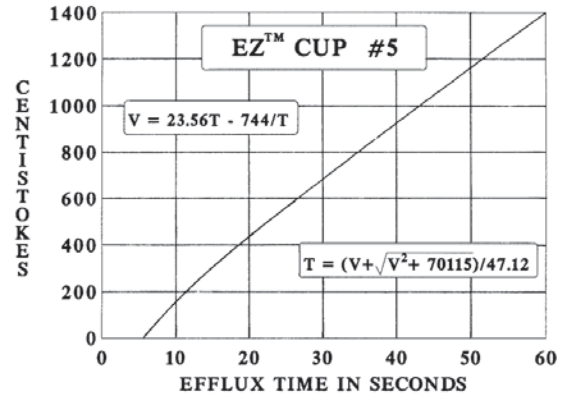
TECHNICAL INFORMATION

The POISE is the fundamental unit of viscosity. It is a defined mechanical measurement of the resistance of a liquid to flow where gravity is not a factor. 100 CENTIPOISE = 1 POISE. However, gravity is the driving force causing liquid in a viscosity cup to flow through the orifice. A high density material will flow from a cup in a shorter time than a low density material of the same viscosity.









TECHNICAL INFORMATION (CONT'D)

The STOKE is defined as the POISE divided by density (or weight per gallon times 0.120). 100 CENTISTOKES = 1 STOKE. The CENTISTOKE is the unit of reference in all viscosity cup measurements.

The graphs at the left of this page and on the preceding page relate viscosity in CENTISTOKES to efflux time in SECONDS for each of the five cups of the EZ™ series. The graphs may be used for determining the rough relationship between these factors but usually reference will be made to the table that is furnished with each EZ™ cup which gives the relationship to the nearest tenth second. If there is a necessity to determine the relationship beyond the range of the table, the mathematical formulas shown on the graphs may be used.

The first of the formulas shown on the graph is used when efflux SECONDS is known. As an example assume 42.5 SECONDS in the No. 2 EZ™ Cup. Multiply 42.5 by 2.80 and the result is 119. Divide 747 by 42.5, which is 17.6 and subtract this value from 119. The result is 101, the CENTISTOKE value of 42.5 SECONDS efflux time from this cup.

The second of the formulas shown on the graph is used when the CENTISTOKE value is known. As an example, assume 825 CENTISTOKES in the No 5 EZ™ Cup. Square 825, which is 680625 and add 70115 for a total of 750740. Take the square root of this value, which is 866 and add 825 for a total of 1691. Divide 1691 by 47.12 and the result is 35.90 SECONDS, the efflux time value of 825 CENTISTOKES from this cup.

VISCOSITY

NOTICE TO ALL GARDCO ZAHN VISCOSITY CUP USERS

Zahn Signature and the improved S90/Signature Series Dip cups do not meet ASTM Specification D4212. Modifying these cups in an attempt to comply with the standards work of the ASTM, as well as others, would be confusing to all users of these series. There would be no easy way of knowing if any particular cup was of the original or modifi ed version. In addition, due to the nature of the cups, it would not have been possible to obtain exact agreement. Not all cups in the Zahn Signature and S90 Series deviate from the evolving standard by the same amount - the range being from near compliance to a variance exceeding a factor of two.

Zahn Signature - S90 cups will continue to be made as long as there is a demand by those who have established their procedures with the use of this instrument. Manufacturing procedures have now been improved, including calibration with oils traceable to the National Institute of Standards and Technology, to provide even greater uniformity of this important series of viscosity cups and to ensure agreement with earlier production. Certifi cation with compliance to ANSI/NCSL Z540 or ISO/IEC 17025. Tables are available which convert between Zahn Signature - S90 and the new EZ™ cups of the same number, to the nearest tenth of a second, to assist those who need to work with both established standards.

INSTRUCTIONS FOR USE

1. Select the proper number cup to be used from the Specification Table, which is dependent on the expected viscosity range of the material to be measured.
2. Ensure that the cup is clean and that there is no residual dried material in or around the orifice.
3. Adjust the temperature, if necessary, of the test material.
4. Completely immerse the cup into the material to be measured in a location free from bubbles or foam, holding the cup vertically by means of the stainless steel split key ring.
5. Measure and record the temperature of the material that is encompassed by the cup.
6. Hold cup vertically by inserting index finger into handle ring. In a quick, steady motion, lift the cup out of the sample material, starting the timer when the top edge of the cup breaks the surface. During the flow time, hold the cup no more than 6” above the level of the sample material.
7. Stop the timer when the first definite break in the stream at the base of the cup is observed.
8. Record the number of seconds of efflux time, temperature and the cup number. (Example: No. 2, EZ™ Dip Cup, 35.0 seconds at 25.1°C.) As an option to the preceding step, refer to the conversion table furnished with the cup and as indicated on the following page, determine the centistoke viscosity for the measured efflux time in seconds and record this value and the measured temperature. (Example: 111.3 centistokes at 25.1°C.)
9. Promptly clean the cup unless it will be used immediately for a rerun of the same material. (Use a length of nylon fishing line to clean the orifice.)

CARE OF CUP

EZ™ viscosity cups are ruggedly constructed with all parts made of stainless steel, except the nameplate, and will give many years of satisfactory service requiring only thorough cleaning after each use. It is recommended, however, that calibration of the cup be confirmed periodically, or if dropped or otherwise subjected to damage, with the appropriate standard oil selected from the specification table. The listed viscosity value of these oils as shown on the container label is traceable to the National Institute of Standards and Technology.

Guide for removing the G-series calibrating oil from Gardco Viscosity Cups

Any remaining material in the cup must be removed by flushing with a suitable solvent. Light naphtha, heptane, octane, highly aromatic solvents, and or any other petroleum-derived hydrocarbon solvent can be used. Varsol® is a commercial solvent that works very well for this purpose.

Completely dry the viscosity cup with a lint free cloth. Use a highly volatile solvent for a second cleaning as since any remaining hydrocarbon solvents from the first process will evaporate quickly after the sample has been flushed from the cup. Hypersolve, MEK and Alcohol can be used in aluminum cups and Hypersolve and Alcohol

for the stainless steel cups. Acetone is commonly used as the second solvent because of its high volatility and its ability to dissolve traces of petroleum solvents and water.

In the third process a low velocity stream of clean air will be sufficient to evaporate remaining traces of any volatile solvent. Be aware, avoid rapid evaporation of these solvents as this can cool the surface to such an extent that humid air may be brought below the dew point, causing a film of water to form on the cup.

Varsol is a registered trademark of the Exxon Company.

CONVERSION TABLE
BETWEEN EFFLUX TIME IN SECONDS AND CENTISTOKES

02/12/88 — GARDCO EZ DIP VISCOSITY CUP #2 — MRE

CONVERSION TABLE

(ACCURATE FOR TRUE LIQUIDS ONLY)

SECONDS	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
	<- - - VISCOSITY IN CENTISTOKES - - - >									
20.0	18.7	19.1	19.6	20.0	20.5	21.0	[illegible]	21.9	22.3	22.8
21.0	23.2	23.7	24.1	24.6	25.0	25.5	[illegible]	26.3	26.8	27.2
22.0	27.6	28.1	28.5	28.9	29.4	29.8	[illegible]	30.7	31.1	31.5
23.0	31.9	32.3	32.8	33.2	33.6	34.0	[illegible]	34.8	35.3	35.7
24.0	36.1	36.5	36.9	37.3	37.7	38.1	[illegible]	38.9	39.3	39.7
25.0	40.1	40.5	40.9	41.3	41.7	42.1	[illegible]	42.9	43.3	43.7
26.0	44.1	44.5	44.8	45.2	45.6	46.0	[illegible]	46.8	47.2	47.6
27.0	47.9	48.3	48.7	49.1	49.5	49.8	[illegible]	50.6	51.0	51.3
28.0	51.7	52.1	52.5	52.8	53.2	53.6	[illegible]	54.3	54.7	55.1
29.0	55.4	55.8	56.2	56.5	56.9	57.3	[illegible]	58.0	58.4	58.7
30.0	59.1	59.5	59.8	[illegible]	60.5	60.9	[illegible]	61.6	62.0	62.3
31.0	62.7	63.1	63.4	63.8	64.1	64.5	[illegible]	65.2	65.5	65.9
32.0	66.3	[illegible]	[illegible]	[illegible]	[illegible]	68.0	[illegible]	68.7	69.1	69.4
33.0	69.8	[illegible]	[illegible]	[illegible]	[illegible]	71.5	[illegible]	72.2	72.5	72.9
34.0	73.2	[illegible]	[illegible]	[illegible]	[illegible]	74.9	[illegible]	75.6	76.0	76.3
35.0	76.7	77.0	77.3	77.7	78.0	78.4	[illegible]	79.0	79.4	79.7
36.0	80.0	80.4	80.7	81.1	81.4	81.7	[illegible]	82.4	82.7	83.1
37.0	83.4	[illegible]	84.1	84.4	84.7	85.1	[illegible]	85.7	86.1	86.4
38.0	86.7	87.1	87.4	87.7	88.1	88.4	[illegible]	89.1	89.4	89.7
39.0	90.0	90.4	90.7	91.0	91.4	91.7	[illegible]	92.3	92.7	93.0
40.0	93.3	93.7	94.0	94.3	94.6	95.0	[illegible]	95.6	95.9	96.3
41.0	[illegible]	96.9	97.2	97.6	97.9	98.2	[illegible]	98.8	99.2	99.5
42.0	[illegible]	100.1	100.5	100.8	101.1	101.4	[illegible]	102.1	102.4	102.7
43.0	103.0	103.3	103.7	104.0	104.3	104.6	[illegible]	105.3	105.6	105.9
44.0	106.2	106.5	106.9	107.2	107.5	107.8	[illegible]	108.4	108.8	109.1
45.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	112.2
[illegible]	[illegible]	112.9	113.2	113.5	113.8	[illegible]	[illegible]	[illegible]	[illegible]	115.4
47.0	115.7	116.0	116.3	116.6	117.0	[illegible]	[illegible]	[illegible]	[illegible]	118.5
48.0	118.8	119.1	119.5	119.8	120.1	[illegible]	[illegible]	[illegible]	[illegible]	121.6
49.0	122.0	122.3	122.6	122.9	123.2	[illegible]	[illegible]	[illegible]	[illegible]	124.8
50.0	125.1	125.4	125.7	126.0	126.3	126.6	126.9	127.2	127.5	127.8
51.0	128.2	128.5	128.8	129.1	129.4	129.7	130.0	130.3	130.6	130.9
52.0	131.2	131.5	131.8	132.2	132.5	132.8	133.1	133.4	133.7	134.0
53.0	134.3	134.6	134.9	135.2	135.5	135.8	136.1	136.4	136.8	137.1
54.0	137.4	137.7	138.0	138.3	138.6	138.9	139.2	139.5	139.8	140.1
55.0	140.4	140.7	141.0	141.3	141.6	141.9	142.2	142.5	142.9	143.2
56.0	143.5	143.8	144.1	144.4	144.7	145.0	145.3	145.6	145.9	146.2
57.0	146.5	146.8	147.1	147.4	147.7	148.0	148.3	148.6	148.9	149.2
58.0	149.5	149.8	150.1	150.4	150.7	151.0	151.3	151.6	151.9	152.2
59.0	152.5	152.8	153.1	153.4	153.7	154.0	154.3	154.6	154.9	155.2
60.0	155.6	155.9	156.2	156.5	156.8	157.1	157.4	157.7	158.0	158.3

EXAMPLE: 53.8 SECONDS = 136.8 CENTISTOKES

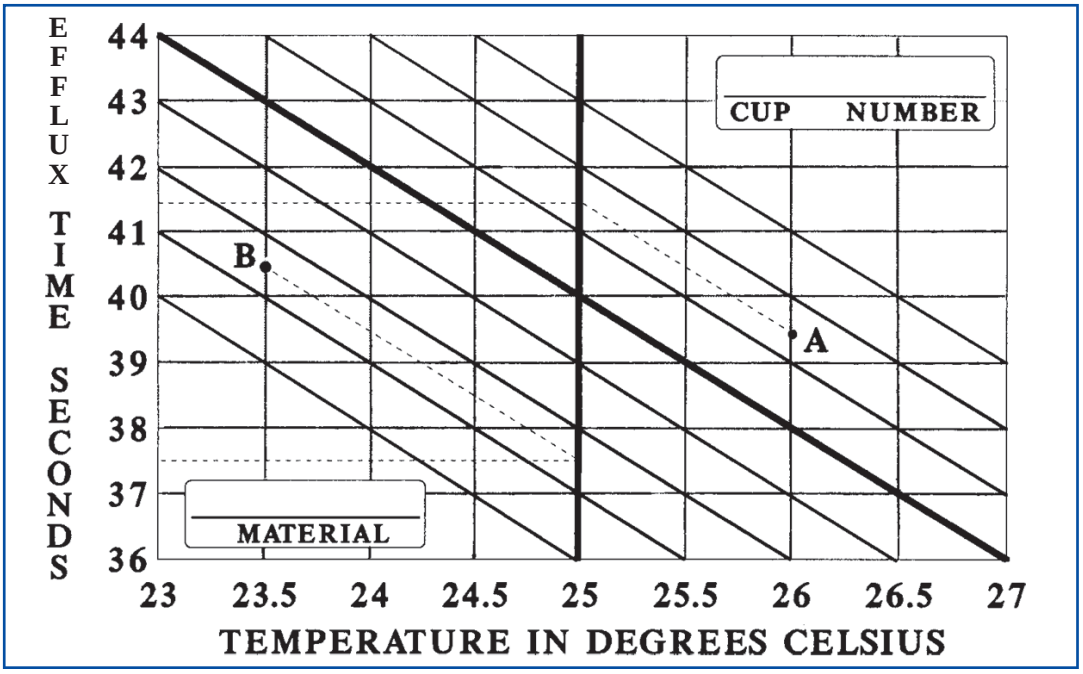
Flow characteristics of the EZ™ Dip Viscosity Cups are very accurately defined by mathematical formula relating them to the viscosity of standard oils which are traceable to the National Institute of Standards and Technology. The formula for each cup in the series is shown on the cup graphs of prior pages. For convenience, the formula for each cup has been solved for each tenth second within the normal cup range. Results are available in table form as shown above and are furnished with each cup. They are also available in sets of five for the five cup series.

Use the table as follows: Assume an efflux time of 45.6 seconds. Read down the left column to the 45.0 line and then to the right on this line to the 0.6 column. The value at the intersection is 111.3 centistokes. The tables may be read in reverse to find efflux time in seconds from a known centistoke value.

VISCOSITY

TEMPERATURE

Most materials change in viscosity as a function of temperature. Those normally measured with viscosity cups change in the range of 3% to 8% per degree Celsius change in temperature. Usually, the higher the viscosity the greater the change. For acceptable accuracy it is necessary to measure temperature at the same time that viscosity cup readings are taken. When many determinations are to be made on similar products in the same viscosity range, it may be helpful to produce a graph for converting measured temperature and viscosity cup efflux time in seconds to seconds at a specified temperature, normally 25° Celsius.



There are three variables to consider: viscosity, efflux time and temperature. All three can be shown on a graph with a family of curves as shown in the following example. Viscosity level is indicated by the diagonal lines, increasing from the lower right to the upper left. Such a graph can be prepared for a given material by taking readings with the EZ™ cup over a limited temperature range as shown in the example. Within this limited range the plots of the obtained data will normally result in a straight line such as the heavy diagonal line. Draw parallel lines as shown which represent different viscosity levels. Enter on the graph the material represented and the EZ™ designation with cup number.

Use the prepared graph by plotting on it measured temperature and efflux time in seconds. At "A" in the example these values are 26.0°C and 39.5 seconds. Read parallel to the diagonal lines to the intersection with the heavy vertical line which is 25.0°C, the target temperature. Reading horizontally to the left it is found that the corrected efflux time in seconds at 25°C is 41.5 seconds. Similarly, at "B" in the example, it is found that a reading taken at 23.5°C, when corrected to 25.0°C changes from 40.5 to 37.5 seconds.

Compensating for a measured temperature near to, but not as specified, must be with caution. Even within the limited range of ±2.0°C the variation of the viscosity with temperature may not be truly linear and any thinning materials used to adjust viscosity may also change the rate of this variation.

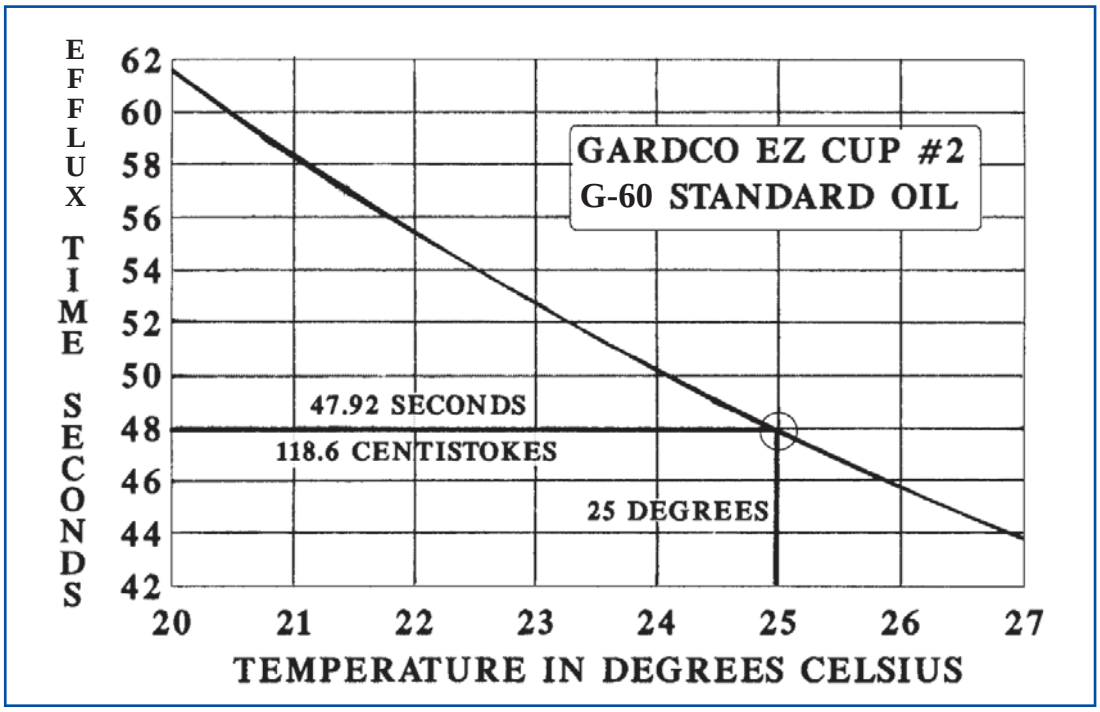
STANDARD "G" SERIES OILS

Warning: Silicone fluids should not be used to calibrate viscosity cups. These materials change the interface between the cup surface and the test material and therefore change the cup calibration. The following is taken from ASTM D445: Viscometers used for silicone fluids should be reserved for the exclusive use of such fluids. Solvent washings from these viscometers should not be used for cleaning other viscometers.

Gardco produced viscosity cups are calibrated with standard "G" series oils. These standard calibration oils prepared expressly by the Cannon Instrument Company for the Paul N. Gardner company are produced with an ISO 9001 certified Quality Management System, comply with the requirements and guidance of ISO 17034 and the quality control is done from an ISO/IEC 17025 accredited laboratory.

Centistokes viscosity of these oils is traceable to the National Institute of Standards and Technology. These oils are available from the Paul N. Gardner company.

Shown in the graph is the viscosity cup number and the standard "G" oil used for its calibration. Normally, cup calibration is at 25 degrees Celsius, shown on the graph by bold lines intersecting with the curve in the circle. Graphs for all cups in the EZ series are included with each cup sold by Paul N. Gardner company.



Viscosity of most liquids, including the standard oils, are dependent on temperature. Efflux time in seconds for the indicated cup-oil combination from twenty (20) to twenty seven (27) degrees Celsius is shown in the graph. The cup may be checked with the indicated "G" oil with reasonable accuracy within these limits. For best accuracy, the temperature of the standard oil should be 25°C. The standard oil value in centistokes is printed on the standard oil bottle label. Conversion from viscosity to efflux time in seconds is by formula or table which defines the characteristics of the cup. The applicable formula and table are furnished with each cup by the Paul N. Gardner Company and authorized distributors.

VI-EZ1	No. 1 EZ™ Dip Viscosity Cup with Conversion Table	
VI-EZ1C	Certified No. 1 EZ™ Dip Viscosity Cup w/Conversion Table	
VI-EZ2	No. 2 EZ™ Dip Viscosity Cup with Conversion Table	
VI-EZ2C	Certified No. 2 EZ™ Dip Viscosity Cup w/Conversion Table	
VI-EZ3	No. 3 EZ™ Dip Viscosity Cup with Conversion Table	
VI-EZ3C	Certified No. 3 EZ™ Dip Viscosity Cup w/Conversion Table	
VI-EZ4	No. 4 EZ™ Dip Viscosity Cup with Conversion Table	
VI-EZ4C	Certified No. 4 EZ™ Dip Viscosity Cup w/Conversion Table	
VI-EZ5	No. 5 EZ™ Dip Viscosity Cup with Conversion Table	
VI-EZ5C	Certified No. 5 EZ™ Dip Viscosity Cup w/Conversion Table	
VI-3803	G-10 Certified Viscosity Standard — Pint	
VI-3815	G-60 Certified Viscosity Standard — Pint	
VI-3821	G-200 Certified Viscosity Standard — Pint	
VI-3825	G-350 Certified Viscosity Standard — Pint	
VI-VCC	Viscosity Cup Equivalent Wall Chart	FREE

Equivalent Charts cover Gardco Calibrated Viscosity Cups and are based on conversion formulas of a type & with parameters as referenced in The Encyclopedia of Polymer Science & Engineering (Vol. 4, Second Edition, John Wiley & Sons, Inc.). Standard oils traceable to the National Institute of Standards & Technology were used in experimental development of these formulas.

Accessories

PU-G201	Instruction Manual EZ Series, includes Grid Set	
PU-G260	Set, 5 Conversion Tables — Zahn Signature and EZ Cups (Seconds Between Zahn Signature and EZ Cups 1, 2, 3, 4 and 5) NIST,	
VI-EZC	ANSI/NCSL Z540 or ISO/IEC 17025 Calibration Certificate	
VI-201901	Aluminum Carousel Stand w/ 5 hooks	
TM-AX705	Ultimate Stopwatch, 1/100 Second	
TM-AX705/C	Certified Ultimate Stopwatch, 1/100 Second, Traceable to N.I.S.T.	
TH-0482	Thermometer, Glass, blue spirit filled, 20° to 30°C	
TH-16100860	Thermometer, Stainless 8" Stem, 25° to 125°F	
TH-16100875	Thermometer, Stainless 8" Stem, 0° to 50°C	
TH-36036-FC	Platinum RTD Dual Therm/Probe (-76 to 500°F/-60 to 260°C)	
LA-2029060	Griffin Beaker, 600ml	

Viscosity Cups are non-returnable items. Subject to final sale.

G SERIES VISCOSITY STANDARDS

FOR USE WITH GARDCO VISCOSITY CUPS

These standard oils are prepared expressly by the Cannon Instrument Company, an ISO/IEC 17025 accredited calibration lab, for the Paul N. Gardner company and are produced in accordance with the requirements and guidance of ISO 17034 and ISO 9001.

These standards provide the greatest possible accuracy in viscosity measurements with Gardco produced and calibrated viscosity cups. A list of “G” Series viscosity standards is available for periodic checking of these measuring instruments. See list on following page.

PACKAGING - LABELING

All viscosity standards are packaged in sealed, dark glass bottles. Net content of each bottle is 0.47 Liter (1 Pint). The product label provides the Standard Name, Lot No., Termination Date, Viscosity in Centistokes at 25.00°C (77.00°F)* and a statement that the standard “is prepared expressly for Paul N. Gardner Co., Inc.” by the Cannon Instrument Company and that data on the standard is traceable to the National Institute of Standards and Technology. A Material Safety Data Sheet (M.S.D.S.) accompanies each bottle of oil.

* With the exception of the Parlin Cups whose Viscosity in Centistokes is measured at 23°C.

USE OF STANDARD OILS

Recommended use of a standard oil to check the calibration of a Gardco produced viscosity cup is as follows: Conversion formulas are either provided with the cup to be checked or are available for the cup.

IMPORTANT LIMITATIONS

Use of standard oils available from Paul N. Gardner are NOT recommended for use with cups produced by other suppliers unless the conversion formula between centistoke viscosity and efflux time as well as cup production tolerance for the particular cup in question has been furnished.

G SERIES VISCOSITY STANDARDS

Standard Oil	Centistoke* Viscosity @25°C	EZ™ Cup No.	S90 Zahn Cup No.	Mini Ford Dip Cup No.	Gardco/ Fisher Dip Cup No.	Fisher Standard Cup No.	Std. Ford & Std. Ford Dip Cup No.	Gardco/ ISO & ISO Dip Cup mm	Gardco/ Din & Din Dip Cup mm	Parlin Cup No.
G-6	8.9	-	-	0	-	-	0	-	-	-
G-10	19	1	-	1	-	-	1	3	-	-
G-20	35	-	1	-	1	1	-	-	-	-
G-34	64	-	-	2	2	2	2	4	-	-
† G-35-P	64	-	-	-	-	-	-	-	-	1
G-60	120	2	2	3, 4	3	3	3, 4	-	-	-
G-100	230	-	3	-	-	-	-	6	4	-
† G-100-P	270	-	-	-	-	-	-	-	-	2
G-200	450	3, 4	-	5	4	4	5	-	-	-
G-350	880	5	4, 5	-	-	-	-	**8	-	-
† G-350-P	810	-	-	-	-	-	-	-	-	3
† G-J3000-P	10,800	-	-	-	-	-	-	-	-	4

*These are nominal values. For the actual centistoke value of the standard, refer to the value on the bottle label.
**NOTE: The 8mm ISO Cup is not available in the Dip version.
† **Special temperature @ 23°C.**

Efflux time to the nearest 0.1 second can be read from the conversion chart provided in this manual or a formula can be used as follows:

1. Select the formula relating viscosity to time of efflux in seconds when viscosity in centistokes is known.
2. Substitute the standard label value for centistokes for "V" in the equation and solve the equation. The resulting value is design efflux (drain) time in seconds.
   NOTE: This determined efflux time is for the standard at 25.00°C (77.00°F) only*.
3. Make a minimum of three determinations with the cup in question on the applicable standard, adhering to the method of use prescribed in the product leaflet or in the applicable ASTM method, and calculate the average efflux time.
   NOTE: Pay particular attention to temperature at time of measurement. Use a thermometer that can be read to the nearest 0.1°C or 0.2°F. Experimental results should NOT be compared against determined design efflux time unless temperature at time of measurement was within ± 0.2° of 25.0°C or ± 0.4° of 77.0°F*. The standard oils change in viscosity between 3% and 8%, depending on the viscosity of the standard, for each degree change in temperature from 25°C*.
4. Compare the experimentally determined efflux time with the design efflux time. If experimental results were at 25.0°C or 77.0°F*, the comparison should be within the following limits:

** With the exception of the Parlin Cups whose Viscosity in Centistokes is measured at 23°C.*

Gardco EZ™Zahn (ASTM) Dip Cups ... 3%	Gardco/ISO Cups 2%
Gardco S90/Zahn Sig. Dip Cups 5%	Gardco/ISO 8mm Cup 3%
Gardco Mini Ford Dip Cups 4%	Gardco/ISO Dip Cup..... 3%
Gardco/Fisher Dip Cups 2%	Gardco/DIN Cup 3%
Gardco/Fisher Standard Cup..... 2%	Gardco/DIN Dip Cup..... 3%
Gardco Standard Ford Cups 2%	Gardco Parlin #1 Cup 3%
Gardco Standard Ford Dip #3 ..... 3%	Gardco Parlin #2 Cup 3%
Gardco Standard Ford Dip #4 ..... 2%	Gardco Parlin #3 Cup 3%
Gardco Standard Ford Dip #5 ..... 3%	Gardco Parlin #4 Cup 5%

MANUAL TEMPERATURE ADJUSTMENT

For the technician who does not have automatic temperature control equipment the following procedure may be useful with dip type cups: If the oil to be used is below temperature, place the bottle with the cap slightly loosened no closer than about one foot from an incandescent desk lamp. This will slowly raise the temperature of the oil. When within about one degree of measuring temperature, transfer the required amount of the oil to a glass container of sufficient height and diameter to accommodate the viscosity cup. (Glass is recommended due to its low rate of temperature conductance.) Place the viscosity cup to be used in the oil in the glass container so that it comes to the same temperature as the oil and place a thermometer, preferably glass, in the oil which can also be used as a stirring rod. If necessary to elevate the temperature slightly, simply hold the glass snugly in the hand while stirring the contents gently and observing the change in temperature. If necessary to lower the temperature, dip the bottom of the glass container for a few seconds in water that is 10 to 20 degrees lower than measuring temperature and continue gentle stirring while the temperature slowly lowers. With a little practice it is possible to make measurements very close to the target temperature.

CARE OF STANDARD OILS

The viscosity standards available from Gardco are precision materials. They are accurate to within 0.25% of the label value at specifi ed temperature. This is a much closer tolerance than viscosity measuring devices normally available to users of viscosity cups. Therefore, there is no easy means of checking the standard to insure that it remains at the value listed on the label except through very careful use of the standard to insure its integrity. Included in this care should be making sure that any container used to receive the standard, as well as the cup to be checked, the thermometer and any other stirring device, be absolutely free of contaminants. Immediately following use, the standard should be returned to its labeled container and capped. If there is valid reason to question the original value of the standard, it should be replaced.

The below listed standards are used by the producer of Gardco viscosity cups not only to calibrate the cups but also to certify such calibration under **ANSI/NCSL Z540 or ISO/IEC 17025, compliant with requirements and guidance of ISO 17034 and ISO 9001**, which is available as an extra cost service. One of the requirements under such certification is the replacement of the standard on or before the termination date. Experience has shown, however, that in the absence of contamination, the standards do not materially deteriorate over an extended period of time.

CAUTION: Silicone fluids should not be used to calibrate viscosity cups. These materials change the interface between the cup surface and the test material and therefore change the cup calibration. The following is taken from ASTM D445; Viscometers used for silicone fluids should be reserved for the exclusive use of such fluids. Solvent washings from these viscometers should not be used for cleaning other viscometers.

Cat. No.	Description		Approx. Centistokes	Call for Pricing
VI-3801	G-6	Viscosity Standard	9	
VI-3803	G-10	Viscosity Standard	19	
VI-3805	G-20	Viscosity Standard	34	
VI-3810	G-35	Viscosity Standard	64	
VI-3811	G-35-P	Viscosity Standard	64	
VI-3815	G-60	Viscosity Standard	120	
VI-3819	G-100-P	Viscosity Standard	270	
VI-3820	G-100	Viscosity Standard	230	
VI-3821	G-200	Viscosity Standard	450	
VI-3825	G-350	Viscosity Standard	880	
VI-3826	G-350-P	Viscosity Standard	810	
VI-3842	G-J3000-P	Viscosity Standard	10,800	
A Material Safety Data Sheet is furnished with each bottle of "G" Series Standard Oils				

CLEANING VISCOSITY CUPS AFTER USE

Guide for removing the G-series calibrating oil from Gardco viscosity cups

Any remaining material in the cup must be removed by flushing with a suitable solvent. Light naphtha, heptane, octane, highly aromatic solvents, and or any other petroleum-derived hydrocarbon solvent can be used. Varsol® is a commercial solvent that works very well for this purpose.

Completely dry the viscosity cup with a lint free cloth. Use a highly volatile solvent for a second cleaning as since any remaining hydrocarbon solvents from the first process will evaporate quickly after the sample has been flushed from the cup. Hypersolve, MEK and Alcohol can be used in aluminum cups and Hypersolve and Alcohol for the stainless steel cups. Acetone is commonly used as the second solvent because of its high volatility and its ability to dissolve traces of petroleum solvents and water.

In the third process a low velocity stream of clean air will be sufficient to evaporate remaining traces of any volatile solvent. Be aware, avoid rapid evaporation of these solvents as this can cool the surface to such an extent that humid air may be brought below the dew point, causing a film of water to form on the cup.

Varsol is a registered trademark of the Exxon Company.

PROCEDURE FOR CALIBRATION FOR GARDCO DIP-TYPE VISCOSITY CUPS

THIS INFORMATION PERTAINS ONLY TO VISCOSITY CUPS MADE BY **PAUL N. GARDNER (GARDCO)**

EXAMPLE OF MATERIALS NEEDED
FOR CALIBRATION OF A DIP-TYPE VISCOSITY CUP

A. One GARDCO Dip-Type Viscosity Cup

B. The Conversion Grid sheet (for cup chosen) to convert seconds efflux time (to nearest tenth of a second) to centistoke viscosity. Every Gardco Cup is furnished with such a data sheet.

C. One pint of certified calibration oil (appropriate to cup chosen, see chart below)

Standard Oil	Centistokes* Viscosity	EZ™ Cup No.	S90 Zahn Cup No.	Mini Ford Dip Cup No.	Gardco/ Fisher Dip Cup No.	Std. Ford Dip Cup No.	Gardco/ISO Dip Cup mm	Gardco/Din Dip Cup mm
G-6	8.9	—	—	0	—	—	—	—
G-10	19	1	—	1	—	1	3	—
G-20	34	—	1	—	1	—	—	—
G-35	64	—	—	2	2	2	4	—
G-60	120	2	2	3, 4	3	3, 4	—	—
G-100	230	—	3	—	—	—	6	4
G-200	450	3, 4	—	5	4	5	—	—
G-350	880	5	4, 5	—	—	—	**8	—

*These are nominal values. For the actual centistoke value of the standard, refer to the value on the bottle label.
**NOTE: The 8mm ISO Cup is not available in the Dip version.

D. To insure highest accuracy of calibration, we recommend the use of ASTM mercury filled glass type thermometers having an accuracy of 0.1°C (0.2°F). Use any of the following:

1. Gardco Cat. No. VI-3130 glass mercury filled thermometer, 4-1/2" length, 20-30°C. range.
2. Gardco Cat. No. TH-02232 °C ASTM mercury filled glass thermometer, 10.8" length, 19-27°C. range.
3. Gardco Cat. No. TH-02233 °F ASTM mercury filled glass thermometer, 10.8" length, 66-80°F. range.

E. Container: 600 ml capacity glass beaker LA-2029060. LA-2029100 1000 ml glass beaker is recommended for the Fisher Dip Cup.

F. Gardco Cat. No. TM-AX705 digital electronic stopwatch, 0.01 second.

G. Reference literature:

1. Gardco Viscosity cup leaflet (for cup chosen)
2. Viscosity Cups-Common Questions and Their Answers leaflet
3. Gardco Viscosity Cup Equivalent Wall Chart (VI-VCC) or Slide Chart (VI-9939)
4. Gardco General Catalog

THIS INFORMATION PERTAINS ONLY TO VISCOSITY CUPS MADE BY PAUL N. GARDNER (GARDCO)

PROCEDURE

1. Examine the cup for obvious obstruction or damage to the orifice area and general cleanliness of cup.
2. Select the recommended Certified Viscosity Standard for the cup to be calibrated. Make sure the expiration date for the standard has not passed.
3. Pour a sufficient amount of oil into a 500 ml container to totally submerge the cup.
4. Using a calibrated ASTM mercury-filled thermometer bring oil to target temperature, 25.0°C ± .5°C. Proper temperature is very important. By wrapping a hand around the beaker and slowly stirring oil, the temperature can be slightly raised.
5. Place cup in oil and allow 1 to 5 minutes for cup and oil to reach thermal equilibrium.
6. Raise the cup vertically to a distance of no more than 6” from the surface of the oil. Start timing with a stop watch with accuracy of one tenth second or better as the top edge of the cup breaks the surface of the oil.
7. Leave the thermometer in the beaker to insure the temperature remains constant throughout the run.
8. Stop the timer when the first definite break in the efflux stream occurs near the bottom of the cup. Be sure to keep air bubbles at a minimum; they will sometimes cause an apparent break prematurely.
9. Record time and temperature and repeat. Keep temperature drift between runs at ±.2°C. Disregard any runs that are more than .5 seconds apart.
10. Adjust times for temperature deviation and average three valid runs.
11. Divide the *design time listed on the viscosity standard by the average and determine the correction factor.
12. Determine if the cup is in or out of tolerance according to manufacturer’s specification.

THIS PROCEDURE MEETS THE REQUIREMENTS OF ASTM D4212

* The Design Drain Time in seconds can be calculated by taking the Kinematic viscosity that can be found on the label of your Certified viscosity standard oil label and by using the conversions formula found in your manual, the design drain time can be calculated using the relevant formula.

EXAMPLE OF VISCOSITY CUP CALIBRATION CHECK SHEET

DATE **7/31/17**
CUP NAME **GARDCO EZ™ Zahn (ASTM)** CUP NO. **2**
CUP RING TAG SERIAL NO. **44263**
STATED TOLERANCE **± 3%**

CERTIFIED OIL DATA
CALIBRATION OIL NO. **G60** LOT NO. **90102**
LABEL DUE DATE **5/ 30/17**
DATE OIL FIRST USED ** **7/31/17**
CENTISTOKE VISCOSITY ON LABEL 118.4 CS

CALIBRATION DATA *
RUN NO. 1 **47.53** SECS @ 25.0°C RUN NO.3 **47.65** SECS @ 25.0°C
RUN NO. 2 **47.63** SECS @ 25.0°C AVERAGE **47.60** SECS @ 25.0°C

DESIGN EFFLUX TIME (FROM GARDCO CONVERSION GRID CHART)
47.86 SECS @ 25.0°C
IN TOLERANCE (√) OUT OF TOLERANCE ( )
CORRECTION FACTOR **1.005**
CALIBRATED BY **A.B. Smith** CHECKED BY **L.A. Dawn**

(Only For Cups Made By GARDCO)

* When many different determinations are to be made on similar products in the same viscosity range, it may be helpful to produce a graph for converting measured temperature and viscosity cup efflux time in seconds to seconds at a specified temperature, normally 25.0° C (77.0°F). Refer to "Temperature" in Viscosity Cup leaflet in this manual for a suggested method of preparation for such a graph.

** When finished with standard oil examine it for contamination of any kind. A fine wire mesh filter may be used if dirt specks are noticed. If oil is accidently contaminated with water settled in bottom of tumbler, pour off clean portion of oil and discard contaminated water portion. Pour oil back into bottle and record the date of first use on the label. Stored in normal ambient temperature the oil is good for a year after date of first use, provided it does not become contaminated.

CLEANING VISCOSITY CUPS AFTER USE

Guide for removing the G-series calibrating oil from Gardco viscosity cups

Any remaining material in the cup must be removed by flushing with a suitable solvent. Light naphtha, heptane, octane, highly aromatic solvents, and or any other petroleum-derived hydrocarbon solvent can be used. Varsol® is a commercial solvent that works very well for this purpose. Completely dry the viscosity cup with a lint free cloth. Use a highly volatile solvent for a second cleaning as since any remaining hydrocarbon solvents from the first process will evaporate quickly after the sample has been flushed from the cup. Hypersolve, MEK and Alcohol can be used in aluminum cups and Hypersolve and Alcohol for the stainless steel cups. Acetone is commonly used as the second solvent because of its high volatility and its ability to dissolve traces of petroleum solvents and water. In the third process a low velocity stream of clean air will be sufficient to evaporate remaining traces of any volatile solvent. Be aware, avoid rapid evaporation of these solvents as this can cool the surface to such an extent that humid air may be brought below the dew point, causing a film of water to form on the cup.

Varsol is a registered trademark of the Exxon Company

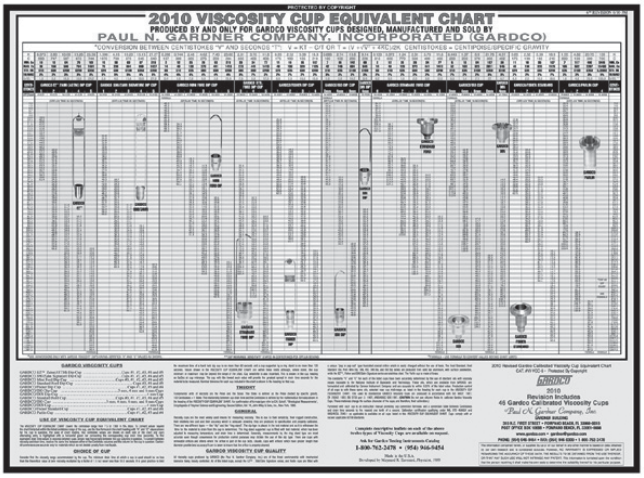
CAUTION

A point of caution: Even the standard oils change in viscosity in the range of 3% - 8% per degree Celsius at the 25° normal measuring range. Temperature of products being measured should be adjusted to within 0.1° of specified temperature if accurate results are to be obtained.

Ask for the *GARDCO*
Viscosity Cup Equivalent Wall Chart
(Item No. VI-VCC)

For Laboratory Use

or Download the spreadsheet
from our website www.gardco.com



Equivalent Charts cover GARDCO Calibrated Viscosity Cups and are based on conversion formulas of a type & with parameters as referenced in The Encyclopedia of Polymer Science & Engineering (Vol. 4, Second Edition, John Wiley & Sons, Inc.). Standard oils traceable to the National Institute of Standards & Technology were used in experimental development of these formulas.

GARDCO EZ™ ZAHN (ASTM) DIP CUPS

There are five orifice sizes in a complete set of EZ™ Dip Viscosity Cups. The recommended use range in seconds for each of the five cups is as follows:

Cup #1	40 to 60 Seconds
Cup #2	20 to 60 Seconds
Cup #3	12 to 60 Seconds
Cup #4	10 to 60 Seconds
Cup #5	10 to 60 Seconds

Cup #1 This cup is used for very thin mixtures where low solids application is desired.

Cup #2 This is the most popular cup of the series and is used for most mixed paints which have been reduced with solvent for application, regardless of the application method. It has wide use in the automotive and similar industries.

Cups #3 & #4 These cups are used for higher solids application where extra heavy coatings are specified.

Cup #5 This cup is normally used for measuring the viscosity of paints prior to reduction with solvent.

INSTRUCTIONS FOR USE

1. Select the proper number cup to be used from the Specification Table, which is dependent on the expected viscosity range of the material to be measured.
2. Insure that the cup is clean and that there is no residual dried material in or around the orifice.
3. Adjust the temperature, if necessary, of the test material.
4. Completely immerse the cup into the material to be measured in a location free from bubbles or foam, holding the cup vertically by means of the stainless steel split key ring.
5. Measure and record the temperature of the material that is encompassed by the cup.
6. Hold cup vertically by inserting index finger into handle ring. In a quick, steady motion, lift the cup out of the sample material, starting the timer when the top edge of the cup breaks the surface. During the flow time, hold the cup no more than 6″ above the level of the sample material.
7. Stop the timer when the first definite break in the stream at the base of the cup is observed.
8. Record the number of seconds of efflux time, temperature and the cup number. (Example: No. 2 EZ™ Dip Cup, 35.0 seconds at 25.1°C.)
   As an option to the preceding step, refer to the conversion table furnished with the cup and as indicated on the following page, determine the centistoke viscosity for the measured efflux time in seconds and record this value and the measured temperature. (Example: 111.3 centistokes at 25.1°C.)
9. Promptly clean the cup unless it will be used immediately for a rerun of the same material. (Use a length of nylon fishing line to clean the orifice.)

EZ™ ZAHN (ASTM) DIP CUPS
CUP #1
CONVERSION FORMULAS AND TABLE©

EZ™ viscosity cups are designed to comply with requirements of ASTM D4212 and to take advantage of design changes known to provide best possible results. Cup dimensions are carefully controlled and cup calibration conditions comply with ANSI/NCSL Z540 or ISO/IEC 17025. Standard viscous oils traceable to the National Institute of Standards and Technology are used in calibration procedures to insure specified efflux time tolerance.

Use this formula derived by Paul N. Gardner company research to find viscosity (V) in centistokes when cup efflux time in seconds (T) is known:

$$V = 0.875T - 993 \div T$$

Use this formula to find cup efflux time in seconds (T) when viscosity (V) in centistokes is known:

$$T = (V + \sqrt{V^2 + 3476}) \div 1.75$$

Results from the above formulas, solved for each tenth of a second within the cup range, are shown on the reverse side of this page. To find centistoke viscosity for a given cup efflux time in seconds, read down the column on the left to find the nearest second. Then, read to the right to the nearest tenth of a second column to find centistoke value. The chart may be read in reverse to find efflux time seconds when viscosity is known.

The EZ™ series of five viscosity cups are produced, calibrated and sold only by the Paul N. Gardner company and authorized distributors.

EZ™ VISCOSITY CUP #1
EFFLUX TIME - CENTISTOKES CONVERSION TABLE©

10/95 **(Accurate for True Liquids Only)**

SECONDS	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
	< — — — — — — — — — — VISCOSITY IN CENTISTOKES — — — — — — — — — — >									
40	10.2	10.3	10.5	10.6	10.8	10.9	11.1	11.2	11.4	11.5
41	11.7	11.8	11.9	12.1	12.2	12.4	12.5	12.7	12.8	13.0
42	13.1	13.3	13.4	13.5	13.7	13.8	14.0	14.1	14.2	14.4
43	14.5	14.7	14.8	15.0	15.1	15.2	15.4	15.5	15.7	15.8
44	15.9	16.1	16.2	16.3	16.5	16.6	16.8	16.9	17.0	17.2
45	17.3	17.4	17.6	17.7	17.9	18.0	18.1	18.3	18.4	18.5
46	18.7	18.8	18.9	19.1	19.2	19.3	19.5	19.6	19.7	19.9
47	20.0	20.1	20.3	20.4	20.5	20.7	20.8	20.9	21.1	21.2
48	21.3	21.4	21.5	21.7	21.8	22.0	22.1	22.2	22.4	22.5
49	22.6	22.7	22.9	23.0	23.1	23.3	23.4	23.5	23.6	23.8
50	23.9	24.0	24.1	24.3	24.4	24.5	24.7	24.8	24.9	25.0
51	25.2	25.3	25.4	25.5	25.7	25.8	25.9	26.0	26.2	26.3
52	26.4	26.5	26.7	26.8	26.9	27.0	27.1	27.3	27.4	27.5
53	27.6	27.8	27.9	28.0	28.1	28.3	28.4	28.5	28.6	28.7
54	28.9	29.0	29.1	29.2	29.3	29.5	29.6	29.7	29.8	30.0
55	30.1	30.2	30.3	30.4	30.6	30.7	30.8	30.9	31.0	31.1
56	31.3	31.4	31.5	31.6	31.7	31.9	32.0	32.1	32.2	32.3
57	32.5	32.6	32.7	32.8	32.9	33.0	33.2	33.3	33.4	33.5
58	33.6	33.7	33.9	34.0	34.1	34.2	34.3	34.4	34.6	34.7
59	34.8	34.9	35.0	35.1	35.3	35.4	35.5	35.6	35.7	35.8
60	36.0	36.1	36.2	36.3	36.4	36.5	36.6	36.8	36.9	37.0

Example: 50.4 Seconds = 24.4 Centistokes.

EZ™ ZAHN (ASTM) DIP CUPS
CUP #2
CONVERSION FORMULAS AND TABLE©

EZ™ viscosity cups are designed to comply with requirements of ASTM D4212 and to take advantage of design changes known to provide best possible results. Cup dimensions are carefully controlled and cup calibration conditions comply with ANSI/NCSL Z540 or ISO/IEC 17025. Standard viscous oils traceable to the National Institute of Standards and Technology are used in calibration procedures to insure specified efflux time tolerance.

Use this formula derived by Paul N. Gardner company research to find viscosity (V) in centistokes when cup efflux time in seconds (T) is known:

$$V = 2.80T - 747 \div T$$

Use this formula to find cup efflux time in seconds (T) when viscosity (V) in centistokes is known:

$$T = (V + \sqrt{V^2 + 8366}) \div 5.60$$

Results from the above formulas, solved for each tenth of a second within the cup range, are shown on the reverse side of this page. To find centistoke viscosity for a given cup efflux time in seconds, read down the column on the left to fi nd the nearest second. Then, read to the right to the nearest tenth of a second column to find centistoke value. The chart may be read in reverse to find efflux time seconds when viscosity is known.

The EZ™ series of five viscosity cups are produced, calibrated and sold only by the Paul N. Gardner company and authorized distributors.

EZ™ VISCOSITY CUP #2
EFFLUX TIME - CENTISTOKES CONVERSION TABLE©

10/95 (Accurate for True Liquids Only)

SECONDS	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
	< — — — — — — — — — VISCOSITY IN CENTISTOKES — — — — — — — — — >									
20	18.7	19.1	19.6	20.0	20.5	21.0	21.4	21.9	22.3	22.8
21	23.2	23.7	24.1	24.6	25.0	25.5	25.9	26.3	26.8	27.2
22	27.6	28.1	28.5	28.9	29.4	29.8	30.2	30.7	31.1	31.5
23	31.9	32.3	32.8	33.2	33.6	34.0	34.4	34.8	35.3	35.7
24	36.1	36.5	36.9	37.3	37.7	38.1	38.5	38.9	39.3	39.7
25	40.1	40.5	40.9	41.3	41.7	42.1	42.5	42.9	43.3	43.7
26	44.1	44.5	44.8	45.2	45.6	46.0	46.4	46.8	47.2	47.6
27	47.9	48.3	48.7	49.1	49.5	49.8	50.2	50.6	51.0	51.3
28	51.7	52.1	52.5	52.8	53.2	53.6	54.0	54.3	54.7	55.1
29	55.4	55.8	56.2	56.5	56.9	57.3	57.6	58.0	58.4	58.7
30	59.1	59.5	59.8	60.2	60.5	60.9	61.3	61.6	62.0	62.3
31	62.7	63.1	63.4	63.8	64.1	64.5	64.8	65.2	65.5	65.9
32	66.3	66.6	67.0	67.3	67.7	68.0	68.4	68.7	69.1	69.4
33	69.8	70.1	70.5	70.8	71.2	71.5	71.8	72.2	72.5	72.9
34	73.2	73.6	73.9	74.3	74.6	74.9	75.3	75.6	76.0	76.3
35	76.7	77.0	77.3	77.7	78.0	78.4	78.7	79.0	79.4	79.7
36	80.1	80.4	80.7	81.1	81.4	81.7	82.1	82.4	82.7	83.1
37	83.4	83.7	84.1	84.4	84.7	85.1	85.4	85.7	86.1	86.4
38	86.7	87.1	87.4	87.7	88.1	88.4	88.7	89.1	89.4	89.7
39	90.0	90.4	90.7	91.0	91.4	91.7	92.0	92.3	92.7	93.0
40	93.3	93.7	94.0	94.3	94.6	95.0	95.3	95.6	95.9	96.3
41	96.6	96.9	97.2	97.6	97.9	98.2	98.5	98.8	99.2	99.5
42	99.8	100.1	100.5	100.8	101.1	101.4	101.7	102.1	102.4	102.7
43	103.0	103.3	103.7	104.0	104.3	104.6	104.9	105.3	105.6	105.9
44	106.2	106.5	106.9	107.2	107.5	107.8	108.1	108.4	108.7	109.1
45	109.4	109.7	110.0	110.3	110.7	111.0	111.3	111.6	111.9	112.2
46	112.6	112.9	113.2	113.5	113.8	114.1	114.4	114.8	115.1	115.4
47	115.7	116.0	116.3	116.6	117.0	117.3	117.6	117.9	118.2	118.5
48	118.8	119.1	119.5	119.8	120.1	120.4	120.7	121.0	121.3	121.6
49	122.0	122.3	122.6	122.9	123.2	123.5	123.8	124.1	124.4	124.8
50	125.1	125.4	125.7	126.0	126.3	126.6	126.9	127.2	127.5	127.8
51	128.2	128.5	128.8	129.1	129.4	129.7	130.0	130.3	130.6	130.9
52	131.2	131.5	131.8	132.2	132.5	132.8	133.1	133.4	133.7	134.0
53	134.3	134.6	134.9	135.2	135.5	135.8	136.1	136.4	136.8	137.1
54	137.4	137.7	138.0	138.3	138.6	138.9	139.2	139.5	139.8	140.1
55	140.4	140.7	141.0	141.3	141.6	141.9	142.2	142.5	142.9	143.2
56	143.5	143.8	144.1	144.4	144.7	145.0	145.3	145.6	145.9	146.2
57	146.5	146.8	147.1	147.4	147.7	148.0	148.3	148.6	148.9	149.2
58	149.5	149.8	150.1	150.4	150.7	151.0	151.3	151.6	151.9	152.2
59	152.5	152.8	153.1	153.4	153.7	154.0	154.3	154.6	154.9	155.2
60	155.6	155.9	156.2	156.5	156.8	157.1	157.4	157.7	158.0	158.3

Example: 53.8 Seconds = 136.8 Centistokes.

EZ™ ZAHN (ASTM) CUPS
CUP #3
CONVERSION FORMULAS AND TABLE©

EZ™ viscosity cups are designed to comply with requirements of ASTM D4212 and to take advantage of design changes known to provide best possible results. Cup dimensions are carefully controlled and cup calibration conditions comply with ANSI/NCSL Z540 or ISO/IEC 17025. Standard viscous oils traceable to the National Institute of Standards and Technology are used in calibration procedures to insure specified efflux time tolerance.

Use this formula derived by Paul N. Gardner company research to find viscosity (V) in centistokes when cup efflux time in seconds (T) is known:

$$V = 10.09T - 587 \div T$$

Use this formula to find cup efflux time in seconds (T) when viscosity (V) in centistokes is known:

$$T = (V + \sqrt{V^2 + 23691}) \div 20.18$$

Results from the above formulas, solved for each tenth of a second within the cup range, are shown on the reverse side of this page. To find centistoke viscosity for a given cup efflux time in seconds, read down the column on the left to find the nearest second. Then, read to the right to the nearest tenth of a second column to find centistoke value. The chart may be read in reverse to find efflux time seconds when viscosity is known.

The EZ™ series of five viscosity cups are produced, calibrated and sold only by the Paul N. Gardner company and authorized distributors.

EZ™ VISCOSITY CUP #3
EFFLUX TIME - CENTISTOKES CONVERSION TABLE©

10/95 (Accurate for True Liquids Only)

SECONDS	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
	< VISCOSITY IN CENTISTOKES >									
12	72	74	75	76	78	79	81	82	83	85
13	86	87	89	90	91	93	94	95	97	98
14	99	101	102	103	105	106	107	108	110	111
15	112	113	115	116	117	119	120	121	122	124
16	125	126	127	128	130	131	132	133	135	136
17	137	138	139	141	142	143	144	145	147	148
18	149	150	151	153	154	155	156	157	158	160
19	161	162	163	164	165	167	168	169	170	171
20	172	174	175	176	177	178	179	181	182	183
21	184	185	186	187	188	190	191	192	193	194
22	195	196	198	199	200	201	202	203	204	205
23	207	208	209	210	211	212	213	214	215	217
24	218	219	220	221	222	223	224	225	227	228
25	229	230	231	232	233	234	235	236	238	239
26	240	241	242	243	244	245	246	247	249	250
27	251	252	253	254	255	256	257	258	259	260
28	262	263	264	265	266	267	268	269	270	271
29	272	273	275	276	277	278	279	280	281	282
30	283	284	285	286	287	288	290	291	292	293
31	294	295	296	297	298	299	300	301	302	303
32	305	306	307	308	309	310	311	312	313	314
33	315	316	317	318	319	320	322	323	324	325
34	326	327	328	329	330	331	332	333	334	335
35	336	337	338	340	341	342	343	344	345	346
36	347	348	349	350	351	352	353	354	355	356
37	357	359	360	361	362	363	364	365	366	367
38	368	369	370	371	372	373	374	375	376	377
39	378	380	381	382	383	384	385	386	387	388
40	389	390	391	392	393	394	395	396	397	398
41	399	400	401	403	404	405	406	407	408	409
42	410	411	412	413	414	415	416	417	418	419
43	420	421	422	423	424	425	426	428	429	430
44	431	432	433	434	435	436	437	438	439	440
45	441	442	443	444	445	446	447	448	449	450
46	451	452	453	454	456	457	458	459	460	461
47	462	463	464	465	466	467	468	469	470	471
48	472	473	474	475	476	477	478	479	480	481
49	482	483	484	486	487	488	489	490	491	492
50	493	494	495	496	497	498	499	500	501	502
51	503	504	505	506	507	508	509	510	511	512
52	513	514	515	516	518	519	520	521	522	523
53	524	525	526	527	528	529	530	531	532	533
54	534	535	536	537	538	539	540	541	542	543
55	544	545	546	547	548	549	550	551	553	554
56	555	556	557	558	559	560	561	562	563	564
57	565	566	567	568	569	570	571	572	573	574
58	575	576	577	578	579	580	581	582	583	584
59	585	586	587	588	589	590	592	593	594	595
60	596	597	598	599	600	601	602	603	604	605

Example: 45.5 Seconds = 446 Centistokes.

EZ™ ZAHN (ASTM) DIP CUPS
CUP #4

CONVERSION FORMULAS AND TABLE©

EZ™ viscosity cups are designed to comply with requirements of ASTM D4212 and to take advantage of design changes known to provide best possible results. Cup dimensions are carefully controlled and cup calibration conditions comply with ANSI/NCSL Z540 or ISO/IEC 17025. Standard viscous oils traceable to the National Institute of Standards and Technology are used in calibration procedures to insure specified efflux time tolerance.

Use this formula derived by Paul N. Gardner company research to find viscosity (V) in centistokes when cup efflux time in seconds (T) is known:

$$V = 13.26T - 673 \div T$$

Use this formula to find cup efflux time in seconds (T) when viscosity (V) in centistokes is known:

$$T = (V + \sqrt{V^2 + 35696}) \div 26.52$$

Results from the above formulas, solved for each tenth of a second within the cup range, are shown on the reverse side of this page. To find centistoke viscosity for a given cup efflux time in seconds, read down the column on the left to find the nearest second. Then, read to the right to the nearest tenth of a second column to find centistoke value. The chart may be read in reverse to find efflux time seconds when viscosity is known.

The EZ™ series of five viscosity cups are produced, calibrated and sold only by the Paul N. Gardner company and authorized distributors.

EZ™ VISCOSITY CUP #4
EFFLUX TIME - CENTISTOKES CONVERSION TABLE©

10/95

(Accurate for True Liquids Only)

SECONDS	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
	< — — — — — — — — — — VISCOSITY IN CENTISTOKES — — — — — — — — — — >									
10	65	67	69	71	73	75	77	79	81	83
11	85	87	88	90	92	94	96	98	99	101
12	103	105	107	108	110	112	114	115	117	119
13	121	122	124	126	127	129	131	133	134	136
14	138	139	141	143	144	146	148	149	151	152
15	154	156	157	159	161	162	164	165	167	169
16	170	172	173	175	176	178	180	181	183	184
17	186	187	189	190	192	194	195	197	198	200
18	201	203	204	206	207	209	210	212	213	215
19	217	218	220	221	223	224	226	227	229	230
20	232	233	235	236	238	239	240	242	243	245
21	246	248	249	251	252	254	255	257	258	260
22	261	263	264	266	267	268	270	271	273	274
23	276	277	279	280	282	283	284	286	287	289
24	290	292	293	295	296	297	299	300	302	303
25	305	306	307	309	310	312	313	315	316	317
26	319	320	322	323	325	326	327	329	330	332
27	333	335	336	337	339	340	342	343	344	346
28	347	349	350	351	353	354	356	357	359	360
29	361	363	364	366	367	368	370	371	373	374
30	375	377	378	380	381	382	384	385	387	388
31	389	391	392	394	395	396	398	399	401	402
32	403	405	406	407	409	410	412	413	414	406
33	417	419	420	421	423	424	426	427	428	430
34	431	432	434	435	437	438	439	441	442	443
35	445	446	448	449	450	452	453	455	456	457
36	459	460	461	463	464	466	467	468	470	471
37	472	474	475	477	478	479	481	482	483	485
38	486	488	489	490	492	493	494	496	497	499
39	500	501	503	504	505	507	508	509	511	512
40	514	515	516	518	519	520	522	523	525	526
41	527	529	530	531	533	534	535	537	538	540
42	541	542	544	545	546	548	549	550	552	553
43	555	556	557	559	560	561	563	564	565	567
44	568	570	571	572	574	575	576	578	579	580
45	582	583	584	586	587	589	590	591	593	594
46	595	597	598	599	601	602	603	605	606	608
47	609	610	612	613	614	616	617	618	620	621
48	622	624	625	627	628	629	631	632	633	635
49	636	637	639	640	641	643	644	645	647	648
50	650	651	652	654	655	656	658	659	660	662
51	663	664	666	667	668	670	671	673	674	675
52	677	678	679	681	682	683	685	686	687	689
53	690	691	693	694	695	697	698	700	701	702
54	704	705	706	708	709	710	712	713	714	716
55	717	718	720	721	722	724	725	726	728	729
56	731	732	733	735	736	737	739	740	741	743
57	744	745	747	748	749	751	752	753	755	756
58	757	759	760	762	763	764	766	767	768	770
59	771	772	774	775	776	778	779	780	782	783
60	784	786	787	788	790	791	792	794	795	796

Example: 45.9 Seconds = 594 Centistokes.

EZ™ VISCOSITY CUPS
CUP #5
CONVERSION FORMULAS AND TABLE©

EZ™ viscosity cups are designed to comply with requirements of ASTM D4212 and to take advantage of design changes known to provide best possible results. Cup dimensions are carefully controlled and cup calibration conditions comply with ANSI/NCSL Z540 or ISO/IEC 17025. Standard viscous oils traceable to the National Institute of Standards and Technology are used in calibration procedures to insure specified efflux time tolerance.

Use this formula derived by Paul N. Gardner company research to find viscosity (V) in centistokes when cup efflux time in seconds (T) is known:

$$V = 23.56T - 744 \div T$$

Use this formula to find cup efflux time in seconds (T) when viscosity (V) in centistokes is known:

$$T = (V + \sqrt{V^2 + 70115}) \div 47.12$$

Results from the above formulas, solved for each tenth of a second within the cup range, are shown on the reverse side of this page. To find centistoke viscosity for a given cup efflux time in seconds, read down the column on the left to find the nearest second. Then, read to the right to the nearest tenth of a second column to find centistoke value. The chart may be read in reverse to find efflux time seconds when viscosity is known.

The EZ™ series of five viscosity cups are produced, calibrated and sold only by the Paul N. Gardner company and authorized distributors.

EZ™ VISCOSITY CUP #5
EFFLUX TIME - CENTISTOKES CONVERSION TABLE©

10/95 (Accurate for True Liquids Only)

SECONDS	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
	< — — — — — — — — — — VISCOSITY IN CENTISTOKES — — — — — — — — — — >									
10	161	164	167	170	173	177	180	183	186	189
11	192	194	197	200	203	206	209	212	215	218
12	221	224	226	229	232	235	238	241	243	246
13	249	252	255	257	260	263	266	268	271	274
14	277	279	282	285	288	290	293	296	298	301
15	304	306	309	312	315	317	320	323	325	328
16	330	333	336	338	341	344	346	349	352	354
17	357	359	362	365	367	370	372	375	378	380
18	383	385	388	390	393	396	398	401	403	406
19	408	411	414	416	419	421	424	426	429	431
20	434	437	439	442	444	447	449	452	454	457
21	459	462	464	467	469	472	474	477	479	482
22	485	487	490	492	495	497	500	502	505	507
23	510	512	515	517	520	522	524	527	529	532
24	534	537	539	542	544	547	549	552	554	557
25	559	562	564	567	569	572	574	577	579	581
26	584	586	589	591	594	596	599	601	604	606
27	609	611	613	616	618	621	623	626	628	631
28	633	636	638	640	643	645	648	650	653	655
29	658	660	662	665	667	670	672	675	677	680
30	682	684	687	689	692	694	697	699	701	704
31	706	709	711	714	716	719	721	723	726	728
32	731	733	736	738	740	743	745	748	750	753
33	755	757	760	762	765	767	769	772	774	777
34	779	782	784	786	789	791	794	796	799	801
35	803	806	808	811	813	815	818	820	823	825
36	828	830	832	835	837	840	842	844	847	849
37	852	854	856	859	861	864	866	868	871	873
38	876	878	881	883	885	888	890	893	895	897
39	900	902	905	907	909	912	914	917	919	921
40	924	926	929	931	933	936	938	941	943	945
41	948	950	953	955	957	960	962	965	967	969
42	972	974	977	979	981	984	986	989	991	993
43	996	998	1001	1003	1005	1008	1010	1013	1015	1017
44	1020	1022	1025	1027	1029	1032	1034	1036	1039	1041
45	1044	1046	1048	1051	1053	1056	1058	1060	1063	1065
46	1068	1070	1072	1075	1077	1080	1082	1084	1087	1089
47	1091	1094	1096	1099	1101	1103	1106	1108	1111	1113
48	1115	1118	1120	1123	1125	1127	1130	1132	1134	1137
49	1139	1142	1144	1146	1149	1151	1154	1156	1158	1161
50	1163	1166	1168	1170	1173	1175	1177	1180	1182	1185
51	1187	1189	1192	1194	1197	1199	1201	1204	1206	1208
52	1211	1213	1216	1218	1220	1223	1225	1227	1230	1232
53	1235	1237	1239	1242	1244	1247	1249	1251	1254	1256
54	1258	1261	1263	1266	1268	1270	1273	1275	1278	1280
55	1282	1285	1287	1289	1292	1294	1297	1299	1301	1303
56	1306	1308	1311	1313	1316	1318	1320	1323	1325	1327
57	1330	1332	1335	1337	1339	1342	1344	1347	1349	1351
58	1354	1356	1358	1361	1363	1366	1368	1370	1373	1375
59	1377	1380	1382	1385	1387	1389	1392	1394	1396	1399
60	1401	1404	1406	1408	1411	1413	1415	1418	1420	1423

Example: 45.3 Seconds = 1051 Centistokes.

CALIBRATION OIL STATEMENT
EFFLUX VISCOSITY CUPS

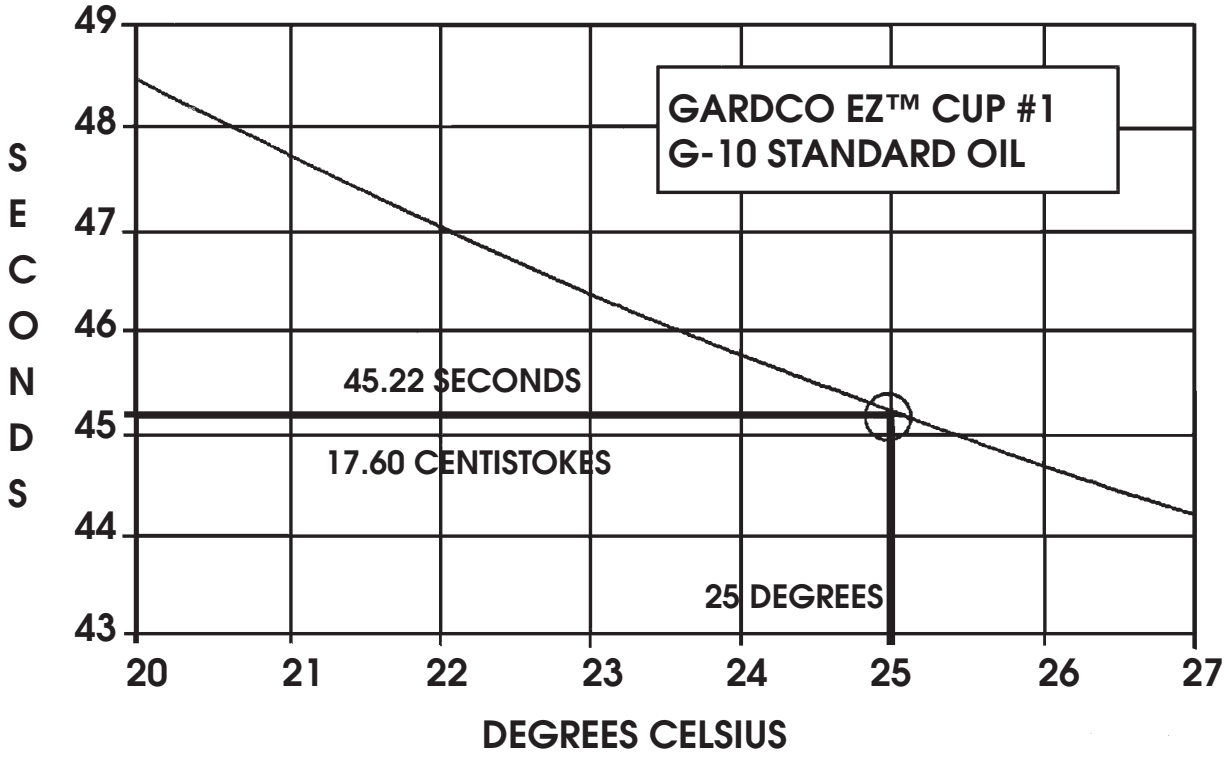
The National Institute of Standards and Technology traceable standard oils used in the calibration of all certifi ed efflux type viscosity cups made and sold by The Paul N. Gardner company (GARDCO) are standard oils prepared expressly for the Paul N. Gardner company (GARDCO) by the Cannon Instrument Company. They are certified in accordance with ISO/IEC 17025.

The following viscosity cups are calibrated with oils produced in accordance with ISO/IEC 17025.

GARDCO Standard Ford Cups.....#0, #1, #2, #3, #4 and #5 Cups
GARDCO ISO Cups .....3mm, 4mm, 6mm, and 8mm Cups
GARDCO DIN Cup .....4mm Cup
GARDCO Parlin Cup.....#1, #2, #3 and #4 Cups
GARDCO Fisher Standard Cups ..... #1, #2, #3 and #4 Cups
GARDCO Standard Ford Dip Cups.....#3, #4 and #5 Cups
GARDCO Mini Ford Dip Cups.....#0, #1, #2, #3, #4 and #5 Cups
GARDCO Mini ISO Dip Cups ..... 3mm, 4mm, and 6mm Cups
GARDCO Mini DIN Dip Cup.....4mm Cup
GARDCO Fisher Dip Cups ..... #1, #2, #3 and #4 Cups
GARDCO EZ™ Zahn (ASTM) Dip Cups .....#1, #2, #3, #4 and #5 Cups
GARDCO S90 Zahn Signature Dip Cups....#1, #2, #3, #4 and #5 Cups

GARDCO® PAUL N. GARDNER
316 NE 1st Street, Pompano Beach, FL 33060
954-946-9454 • www.gardco.com

GARDCO EZ™ VISCOSITY CUPS
EFFLUX TIME IN SECONDS — TEMPERATURE



Gardco produced viscosity cups are calibrated with standard "G" Series oils. Centistoke viscosity of these oils is traceable to the National Institute of Standards and Technology. These oils are available from the Paul N. Gardner company.

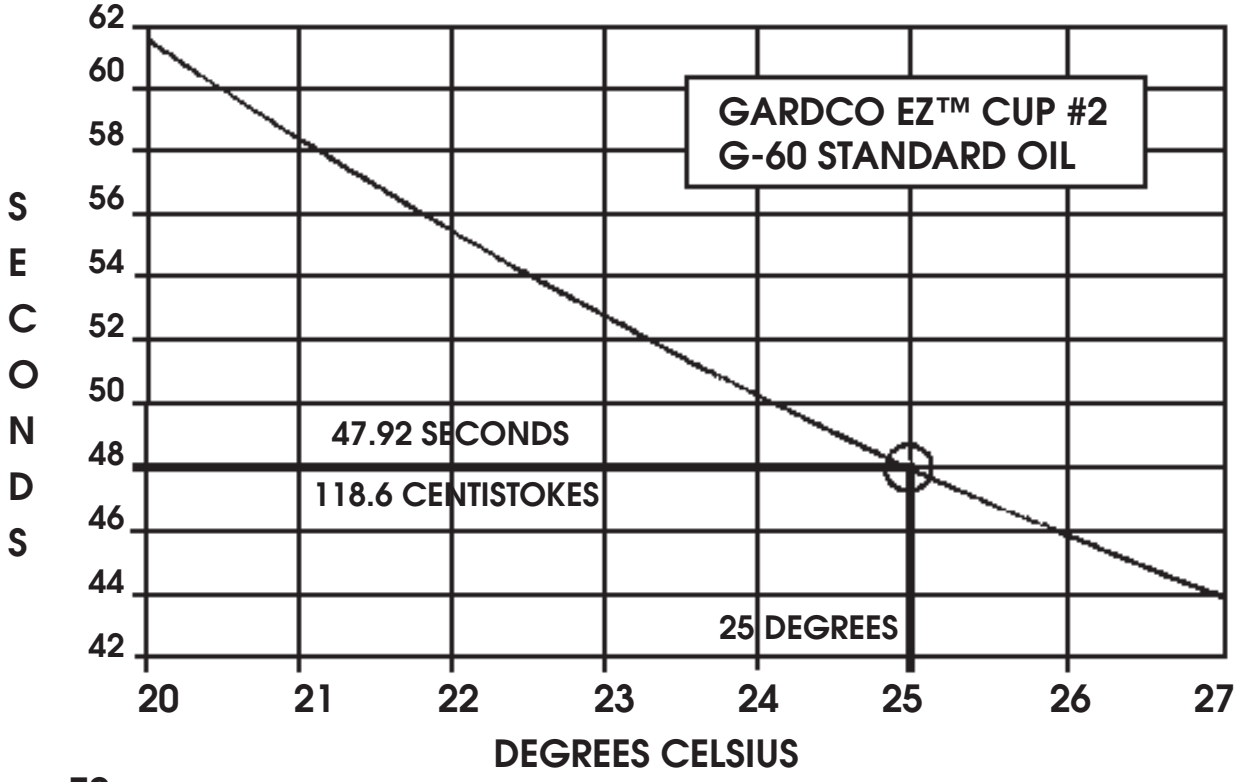
Shown in the above graph is the viscosity cup number and the standard "G" oil used for its calibration. Normally, cup calibration is at 25 degrees Celsius, shown on the graph by bold lines intersecting with the curve in the circle. Graphs for other numbered cups in the series are on following pages.

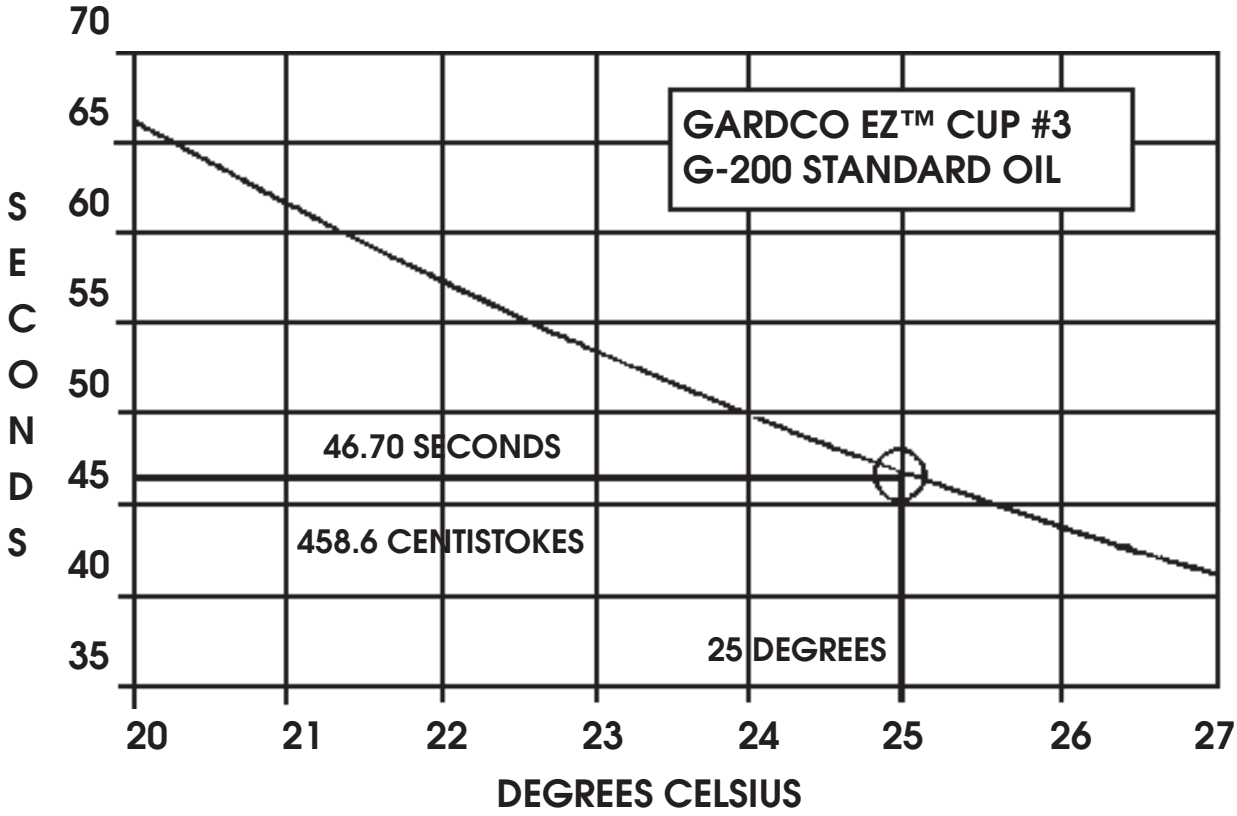
Viscosity of most liquids, including the standard oils, are dependent on temperature. Efflux time in seconds for the indicated cup-oil combination from twenty (20) to twenty seven (27) degrees Celsius is shown in the above graph. The cup may be checked with the indicated "G" oil with reasonable accuracy within these limits. For best accuracy, the standard oil label viscosity with temperature at 25 degrees Celsius should be used. Conversion from viscosity to efflux time in seconds is by the formula or table furnished with the cup. Conversion between degrees Celsius and Fahrenheit is on the reverse side of this page.

This information is included with each viscosity cup sold by the Paul N. Gardner company or by authorized distributors.

GARDCO EZ™ VISCOSITY CUPS

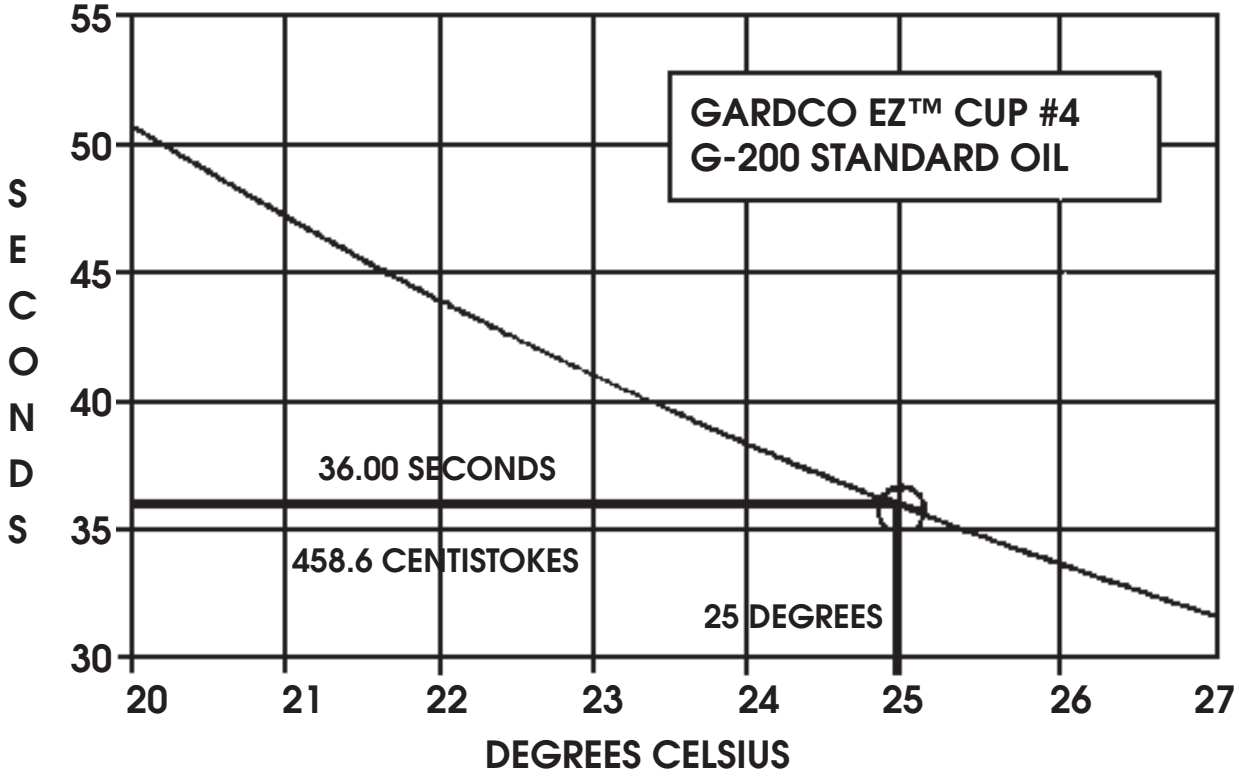
EFFLUX TIME IN SECONDS — TEMPERATURE

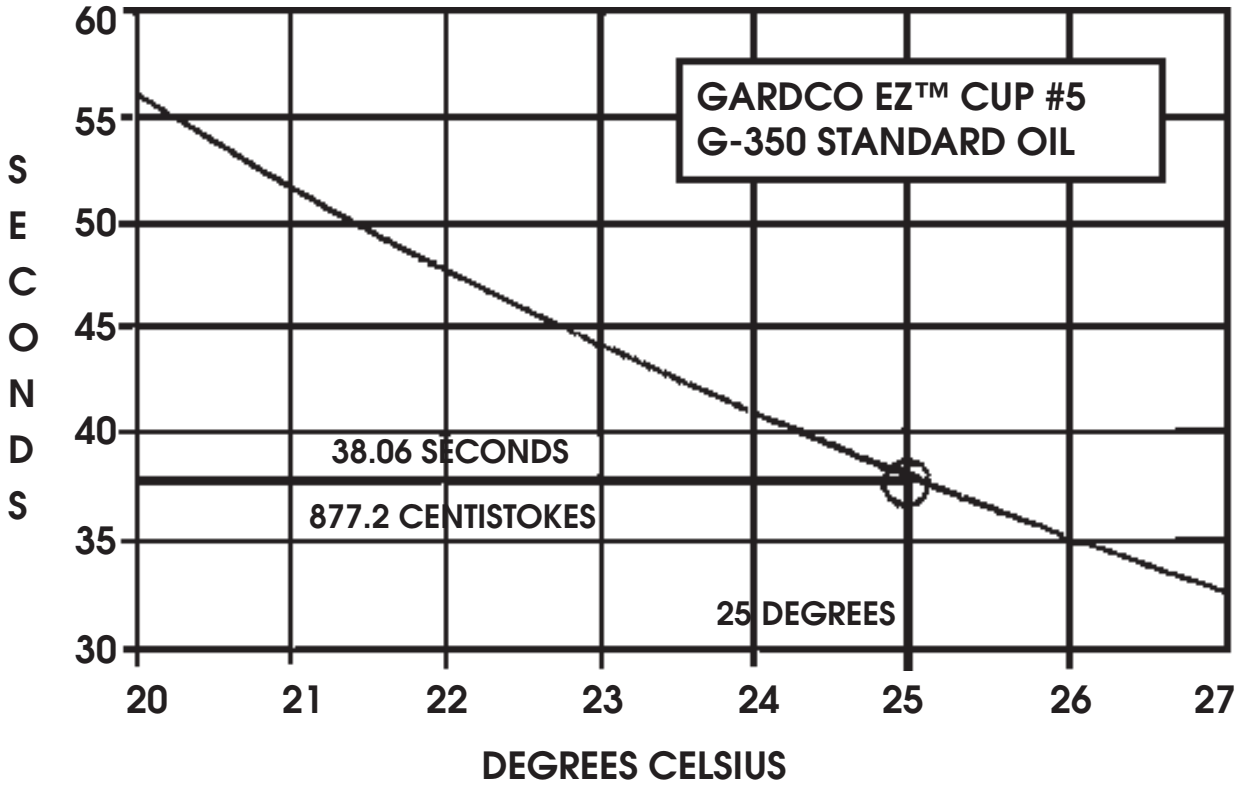




GARDCO EZ™ VISCOSITY CUPS

EFFLUX TIME IN SECONDS — TEMPERATURE





TEMPERATURE SCALE CONVERSION BETWEEN CELSIUS AND FAHRENHEIT

CELSIUS	DEGREES FAHRENHEIT
20.0	68.0
20.1	68.2
20.2	68.4
20.3	68.5
20.4	68.7
20.5	68.9
20.6	69.1
20.7	69.3
20.8	69.4
20.9	69.6
21.0	69.8
21.1	70.0
21.2	70.2
21.3	70.3
21.4	70.5
21.5	70.7
21.6	70.9
21.7	71.1
21.8	71.2
21.9	71.4
22.0	71.6
22.1	71.8
22.2	72.0
22.3	72.1
22.4	72.3
22.5	72.5
22.6	72.7
22.7	72.9
22.8	73.0
22.9	73.2
23.0	73.4
23.1	73.6
23.2	73.8
23.3	73.9
23.4	74.1
23.5	74.3
23.6	74.5
23.7	74.7
23.8	74.8
23.9	75.0
24.0	75.2
24.1	75.4
24.2	75.6
24.3	75.7
24.4	75.9
24.5	76.1
24.6	76.3
24.7	76.5
24.8	76.6
24.9	76.8
25.0	77.0
25.1	77.2
25.2	77.4
25.3	77.5
25.4	77.7
25.5	77.9
25.6	78.1
25.7	78.3
25.8	78.4
25.9	78.6
26.0	78.8
26.1	79.0
26.2	79.2
26.3	79.3
26.4	79.5
26.5	79.7
26.6	79.9
26.7	80.1
26.8	80.2
26.9	80.4
27.0	80.6

F° = (C° x 1.8) + 32
C° = (F° - 32°) ÷ 1.8

A Service To Industry

GARDCO VISCOSITY CUP CERTIFICATION

and

GARDCO INSTRUMENT CERTIFICATION

QUALIFIES UNDER ANSI/NCSL Z540-1 OR ISO/IEC 17025 AS APPLICABLE CALIBRATION OILS TRACEABLE TO N.I.S.T.

GARDCO-produced viscosity cups are calibrated with standard "G" Series oils. Centistoke viscosity of these oils is traceable to the National Institute of Standards and Technology. These standard oils, prepared expressly by the Cannon Instrument Company for the Paul N. Gardner company, are calibrated in accordance with **ISO/IEC 17025**.

GARDCO®

PAUL N. GARDNER

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VISTI Rev. 1 8/13/19

GARDCO VISCOSITY CUP CERTIFICATION

QUALIFIES UNDER ANSI/NCSL Z540-1 OR MIL STD ISO/IEC 17025, ISO 9001 AS APPLICABLE STANDARD "G" CALIBRATING OILS ARE TRACEABLE TO NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

GARDCO VISCOSITY CUP NAME	SIZE	STANDARD "G" OIL NUMBER	CUP FORMULA CONSTANTS K	C	CUP TOLERANCE ± %
GARDCO STANDARD FORD CUP	0	G-6	0.133	313	2
GARDCO STANDARD FORD CUP	1	G-10	0.372	600	2
GARDCO STANDARD FORD CUP	2	G-35	1.24	770	2
GARDCO STANDARD FORD CUP	3	G-60	2.31	550	2
GARDCO STANDARD FORD CUP	4	G-60	3.70	400	2
GARDCO STANDARD FORD CUP	5	G-200	11.80	408	2
GARDCO/ISO CUP	3mm	G-10	0.443	200	2
GARDCO/ISO CUP	4mm	G-35	1.37	200	2
GARDCO/ISO CUP	6mm	G-100	6.90	570	2
GARDCO/ISO CUP	8mm	G-350	21.78	306	3
GARDCO/DIN CUP	4mm	G-100	4.57	452	3
GARDCO/FISHER STANDARD CUP	1	G-20	0.85	175	2
GARDCO/FISHER STANDARD CUP	2	G-35	2.32	190	2
GARDCO/FISHER STANDARD CUP	3	G-60	5.39	185	2
GARDCO/FISHER STANDARD CUP	4	G-200	18.90	210	2
GARDCO STANDARD FORD DIP CUP	3	G-60	2.31	550	3
GARDCO STANDARD FORD DIP CUP	4	G-60	3.70	400	2
GARDCO STANDARD FORD DIP CUP	5	G200	11.80	408	3
GARDCO MINI FORD DIP CUP	0	G-6	0.266	157	4
GARDCO MINI FORD DIP CUP	1	G-10	0.744	300	4
GARDCO MINI FORD DIP CUP	2	G-35	2.48	385	4
GARDCO MINI FORD DIP CUP	3	G-60	4.62	275	4
GARDCO MINI FORD DIP CUP	4	G-60	7.40	200	4
GARDCO MINI FORD DIP CUP	5	G-200	23.60	204	4
GARDCO/ISO DIP CUP	3mm	G-10	0.886	100	3
GARDCO/ISO DIP CUP	4mm	G-35	2.74	100	3
GARDCO/ISO DIP CUP	6mm	G-100	13.80	285	3
GARDCO/DIN DIP CUP	4mm	G-100	9.14	226	3
GARDCO/FISHER DIP CUP	1	G-20	0.85	175	2
GARDCO/FISHER DIP CUP	2	G-35	2.32	190	2
GARDCO/FISHER DIP CUP	3	G-60	5.39	185	2
GARDCO/FISHER DIP CUP	4	G-200	18.90	210	2
GARDCO EZ™ ZAHN (ASTM) DIP CUP	1	G-10	0.875	993	3
GARDCO EZ™ ZAHN (ASTM) DIP CUP	2	G-60	2.80	747	3
GARDCO EZ™ ZAHN (ASTM) DIP CUP	3	G-200	10.09	587	3
GARDCO EZ™ ZAHN (ASTM) DIP CUP	4	G-200	13.26	673	3
GARDCO EZ™ ZAHN (ASTM) DIP CUP	5	G-350	23.56	744	3
GARDCO S90/ZAHN SIGNATURE DIP CUP	1	G-35	1.59	1070	5
GARDCO S90/ZAHN SIGNATURE DIP CUP	2	G-60	4.18	760	5
GARDCO S90/ZAHN SIGNATURE DIP CUP	3	G-100	10.23	575	5
GARDCO S90/ZAHN SIGNATURE DIP CUP	4	G-350	15.13	545	5
GARDCO S90/ZAHN SIGNATURE DIP CUP	5	G-350	27.27	540	5
GARDCO /PARLIN CUP	1	G-35-P	1.55	800	3
GARDCO /PARLIN CUP	2	G-100-P	4.82	100	3
GARDCO /PARLIN CUP	3	G-350-P	20.75	500	3
GARDCO /PARLIN CUP	4	G-J3000-P	139.00	750	5

CONVERSION BETWEEN CENTISTOKES "V" AND CUP DRAIN SECONDS "T":

$V = KT - C \div T$ or $T = (V + \sqrt{V^2 + 4KC}) \div 2K$

WHERE "K" AND "C" ARE THE ABOVE LISTED CONSTANTS

GARDCO

Paul N. Gardner Company, Inc.

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www.gardco.com • email: gardner@gardco.com

VISCOSITY CUP CALIBRATION CERTIFICATE

CERTIFICATE No. CERTIFICATE EFFECTIVE DATE
CUSTOMER CUSTOMER NO.
ADDRESS

( ) GARDCO/ISO DIP CUP ---------- CUP No. SERIAL No.
CENTISTOKES RANGE: 3mm(7 TO 42), 4mm(35 TO 149), 6mm(142 TO 684)
DRAIN TIME TOLERANCE : +/- 3%

( ) GARDCO/DIN DIP CUP ---------- CUP No. SERIAL No.
CENTISTOKES RANGE: 4mm(69 TO 545)
DRAIN TIME TOLERANCE : +/- 3%

( ) GARDCO/FISHER DIP CUP ---------- CUP No. SERIAL No.
CENTISTOKES RANGE: #1(11 TO 48), #2(19 TO 136), #3(35 TO 320), #4(167 TO 1125)
DRAIN TIME TOLERANCE : +/- 2%

( ) GARDCO EZ™ ZAHN (ASTM) DIP CUP ---------- CUP No. SERIAL No.
CENTISTOKES RANGE: #1(10 TO 36), #2(19 TO 156), #3(64 TO 596), #4(78 TO 784), #5(161 TO 1401)
DRAIN TIME TOLERANCE : +/- 3%

( ) GARDCO S90/ZAHN SIGNATURE DIP CUP ---------- CUP No. SERIAL No.
CENTISTOKES RANGE: #1(15 TO 78), #2(39 TO 238), #3(63 TO 440), #4(87 TO 899), #5(219 TO 1627)
DRAIN TIME TOLERANCE : +/- 5%

VISCOSITY STANDARD LOT No. DATE DUE
CENTISTOKES VISCOSITY UNCERTAINTY 0.25%
STANDARD OILS prepared by Cannon Instrument Company, a subsidiary of the Paul N. Gardner Company are produced in accordance with ISO 9002:1994; EN ISO9002:1994; BS EN ISO 9002:1994; ANSI/ASQC Q9002:1994.
APPLICABLE NIST CERTIFICATE No. 246089, May 1990.
THERMOMETER NO
CALIBRATED CALIBRATION DUE NIST NO. UNCERTAINTY 0.05° C.
STOPWATCH NO.
CALIBRATED CALIBRATION DUE CERT. NO. UNCERT. 0.04 SEC.
All standards are traceable to National Institute of Standards and Technology (NIST).
CALIBRATION DATA: ROOM TEMPERATURE ° C ROOM HUMIDITY < %

RUN No. 1.	SEC.@	° C.	SEC.@ 25.0° C.
RUN No. 2.	SEC.@	° C.	SEC.@ 25.0° C.
RUN No. 3.	SEC.@	° C.	SEC.@ 25.0° C.
		AVERAGE----------	SEC.@ 25.0° C.
		DESIGN DRAIN TIME -	SEC.@ 25.0° C.

IN TOLERANCE ( ) OUT OF TOLERANCE ( ) CORRECTION FACTOR

CALIBRATION LAB: MODERN MACHINE & TOOL CO., INC. * 11844 Jefferson Avenue * Newport News, Virginia 23606
COMPLIANT WITH ANSI/NCSL Z540-1-1994 & ISO/IEC 17025 CALIBRATION DATE
PROCEDURE NO. 7.6.3 CALIBRATED BY APPROVED BY

GARDCO® INSTRUMENT CERTIFICATION

QUALIFIES UNDER ANCI/NCSL Z540-1 OR MIL STD ISO/IEC 17025,

AND CONFORMS TO ISO 9000 WHEN ORDERED WITH CALIBRATION CERTIFICATION

GARDCO INSTRUMENT ITEM AND RANGE	ITEM TOLERANCE	ITEM CHECK POINTS	MINIMUM GRADUATIONS
WEIGHT PER GALLON CUPS			
U.S. STANDARD CUP	0.5%	83.205gr	NA
CUP WITH TARE WEIGHT	0.2G	Cup Wt	NA
BRITISH STANDARD CUP	0.5%	99.925gr	NA
CUP WITH TARE WEIGHT	0.2G	Cup Wt	NA
U.S. MINI CUP	1.2%	8.321gr	NA
CUP WITH TARE WEIGHT	0.1G	Cup Wt	NA
TARELITE WEIGHT PER GALLON CUPS			
U.S. STANDARD CUP	2%	83.205gr	NA
CUP WITH TARE WEIGHT	0.2G	Cup Wt	NA
BRITISH STANDARD (100cc) CUP	2%	99.925gr	NA
CUP WITH TARE WEIGHT	0.2G	Cup Wt	NA
BRITISH Standard (50cc) CUP	2%	49.963gr	NA
CUP WITH TARE WEIGHT	0.1G	Cup Wt	NA
WET FILM THICKNESS GAGE	**Mils**	**Mils**	**Mils**
MODEL C, 0 - 2 MILS	0.2	.5, 1, 1.5	0.1
MODEL C, 0 - 4 MILS	0.2	1, 2, 3	0.2
MODEL C, 2 - 12 MILS	0.4	4, 7, 10	0.5
MODEL C, 10 - 30 MILS	0.5	15, 20, 25	1.0
MODEL C, 20 - 60 MILS	0.5	30, 40, 50	2.0
WET FILM THICKNESS GAGE	**MILS MICRONS**	**MILS MICRONS**	**MILS MICRONS**
MODEL IC 0 - 1 MILS / 0 - 25 MICRONS	0.1 2.5	.25,.5,.75 5,13,20	.05 1.0
MODEL IC 0 - 2 MILS / 0 - 50 MICRONS	0.2 5.0	.5,1,7.5 10,26,40	0.1 2.0
MODEL IC 0 - 4 MILS / 0 - 100 MICRONS	0.2 5.0	1,2,3 20,52,80	0.2 4.0
MODEL IC 2 - 12 MILS / 50 - 300 MICRONS	0.4 10	4,7,10 100,180,250	0.5 10
MODEL IC 10 - 30 MILS / 250 - 750 MICRONS	0.5 13	15,20,25 380,500,640	1.0 20
MODEL IC 20 - 60 MILS / 500 - 1500 MICRONS	0.5 13	30,40,50 760,1000,1280	2.0 40
WET FILM THICKNESS GAGE	**MILS**	**MILS**	**MILS**
MODEL CC 2-6 MILS	0.2	3,4,5	0.2
MODEL CC 4-8 MILS	0.2	5,6,7	0.2
GUARDED RING TENSIONED THICKNESS STANDARD	**MILS**	**MILS**	
GRTTS. 1.0 MIL NOMINAL	0.1	1	NA
GRTTS, 2.0 MIL NOMINAL	0.1	2	NA
GRTTS, 5.0 MIL NOMINAL	0.1	5	NA
UNIVERSAL APPLICATOR, ADJUSTABLE BLADE TYPE	**MILS**	**MILS**	**MILS**
2" BLADE, 0 - 50 MILS	1.0	0,25,50	1.0
4" BLADE, 0 - 50 MILS	1.0	0,25,50	1.0
6" BLADE, 0 - 50 MILS	1.0	0,25,50	1.0
8" BLADE, 0 - 50 MILS	1.0	0,25,50	1.0
10" BLADE, 0 - 50 MILS	1.0	0,25,50	1.0
12" BLADE, 0 - 50 MILS	1.0	0,25,50	1.0
2" BLADE, 0 - 10 MILS	0.5	0,5,10	0.2
4" BLADE, 0 - 10 MILS	0.5	0,5,10	0.2
6" BLADE, 0 - 10 MILS	0.5	0,5,10	0.2
8" BLADE, 0 - 10 MILS	0.5	0,5,10	0.2
10" BLADE, 0 - 10 MILS	0.5	0,5,10	0.2
12" BLADE, 0 - 10 MILS	0.5	0,5,10	0.2
PERMEABILITY CUP	**MM**	**MM**	
STANDARD DIAMETER	.05	56.4	NA
STANDARD HEIGHT	.05	10	NA
P-A-T BLADES	**MM**	**MM**	
1.0MM - 6 TEETH	.05	1.0	NA
1.0MM - 11 TEETH	.05	1.0	NA
1.5MM - 11 TEETH	.05	1.5	NA
2.0MM - 6 TEETH	.05	2.0	NA
3.0MM - 6 TEETH	.05	3.0	NA
5.0MM - 5 TEETH	.05	5.0	NA
	INCH	**INCH**	
3/32 - 4 TEETH	.002	3/32	NA

Viscosity measurement

Understanding various types of equipment and the influencing factors in the measurement.

M.R. Euverard, Paul N. Gardner Co., Pompano Beach, FL

■ All fluids resist forces to change their form. Many solids, such as tar, show a gradual yielding to forces tending to change their form. This property (like an internal friction) is called viscosity. Classical physics defines the viscosity of a substance as the tangential force per unit area of either of two horizontal planes at unit distance apart. One is fixed, while the other moves at unit velocity. The space is filled with the substance. It is expressed in dyneseconds per square centimeter or poises. One poise equals 100 centipoises.

Rotational instruments

Many of the instruments used in measuring viscosity are rotational type—" bob in a cup," "cone and plate" or variations of these forms. The results gathered from these instruments read in basic units or poises. They are obtained through a knowledge of the surface area in contact with the substance being measured and the separation of these surfaces.

Rotational instruments can be engineered to accommodate a very wide range of viscosity values. The more elaborate devices provide values at different rates of shear. This provides a thorough study of the viscous properties of a substance. Auxiliaries such as automatic recorders may be used.

There are some disadvantages to the rotational instruments. They are very complex and costly. Though usually large and bulky, they may be delicate and require practiced techniques for good results. Probably one of their biggest problems lies in temperature control. At high rates of shear the substance being measured heats up. To retain a given temperature, an elaborate temperature sensing and control system is required.

Orifice—capillary instruments

Capillary tube type instruments are limited to measurements on relatively low-viscosity substances. There are many different configurations. In simple form, they consist of a reservoir with a capillary tube of known length and internal diameter connecting another reservoir at a lower level. The substance to be measured is filled into the upper reservoir.

Figure 1. Standard Ford viscosity cup.

The time for this exact amount to flow to the lower reservoir is determined. Another factor is now introduced—density of the substance. A material of high density should flow through the capillary tube faster than one of low density (at the same viscosity).

The volume of flow of a substance through a tube is directly proportional to: the time of flow; pressure across the tube; and the fourth power of the tube radius. It is inversely proportional to the length of the tube and the viscosity of the substance. Also, by definition, kinematic viscosity (the stoke) is the ratio of poise viscosity to density. The stoke equals 100 centistokes.

The capillary tube-type instruments also tie directly to basic units of measurement. However, if gravity is the driving force creating the pressure drop across the tube, then density is a factor and the results are in stokes.

The capillary tube type instrument is an accurate device for measurement in the lower part of the viscosity spectrum. But, again, there are limitations. They are fragile and limited to very low rates of shear. These instruments are not easily adaptable to field use.

Orifice flow instruments—known as viscosity cups—are an outgrowth of the capillary tube instruments. In the cups, the tube is much shorter in length and larger in diameter. Normally, they accommodate a larger sample than the reservoir of the capillary tube. There is a deviation from linearity at the low end of each cup range. The degree of deviation is more pronounced in cups with the shorter effective length of tube. This is due to the formation of eddy currents at higher rates of flow.

Since gravity is the driving force for the flow of a material from a viscosity

cup—and density is a factor—the measurement is in terms of kinematic viscosity, or stokes.

There are many reasons why viscosity cups are so widely used—they are very accurate, rugged and suitable for field use, relatively easy to clean and inexpensive.

Development of viscosity cups has taken place in two directions: one type for use in the control laboratory and the other, usually in simpler form, for use in the field. The biggest problem with this class of device is probably the absence of standardization and a tieback to basic units of measurement.

Liquid-solid mixtures

Liquid-solid mixtures introduce a very complex dimension to viscosity measurement. Some materials will not flow at all until a force exceeding a certain minimum is imposed. Some will reflect a lowering and some an increase in viscosity as the rate of shear is increased.

Evaluation of the flow properties of these mixtures (where the solid component is relatively high) is best done on rotational type equipment. Here, the rate of shear is variable.

Temperature

Temperature influences most physical measurements. In the range of room temperature, a soft iron bar will change in length by 0.00121 percent for each degree Centigrade change in temperature. This small amount can be neglected for most purposes. The influence of temperature in viscosity measurements of liquids is much more severe. Consider a volume of water under the same conditions. The change is over 20 times greater and must be considered in most accurate volume measurements. This includes the calibration of weight per gallon cups. One group of refined mineral oils used for the calibration of viscosity measuring instruments changes considerably in actual viscosity. An average change of more than five percent for each degree centigrade change in temperature in the range of 25°C is common. This is over 200 times the influence of temperature on a volume of water. It is also over 4,000 times the influence on the length of a soft iron bar.

Errors that are often made in temperature measurement (and therefore in viscosity measurement) involve one or more of the following:

- The thermometer may cover too wide a range and therefore is not sensitive enough.
- The time lag of the thermometer is too great for the application.
- The "thermal well" effect of the thermometer is too great for the application.
- The sample is not thoroughly mixed and uniform throughout in temperature.
- There is temperature change during the measurement. Surfaces of equipment are a different temperature from that of the sample.

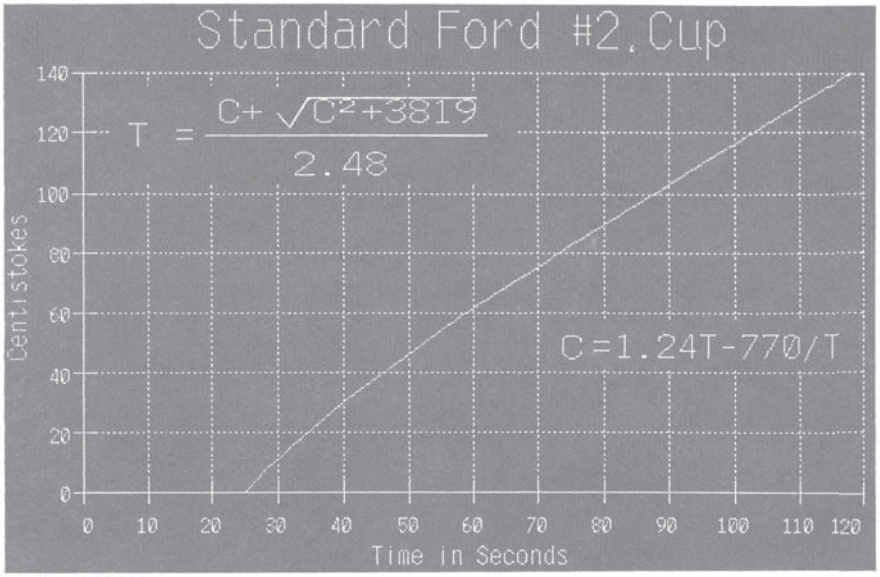

Figure 2. Standard Ford viscosity cup #2.

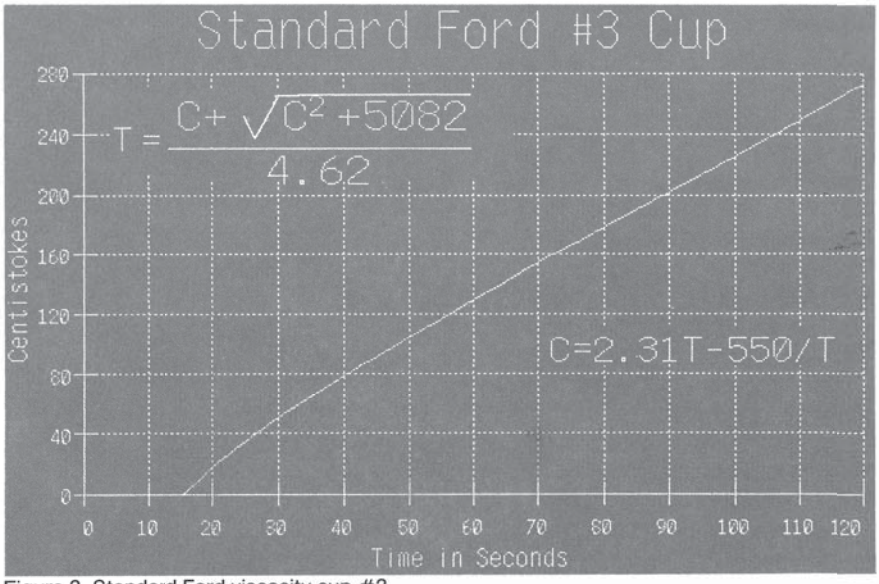

Figure 3. Standard Ford viscosity cup #3.

Ford cup series history

The volume and general flow characteristics of the Ford viscosity cup have not changed over the years. Specifications and definition by mathematical formula now make it a valued tool. It's useful not only for product development, but also for production control.

The first known industry attempt to relate the results of various types of viscosity cups was by a subcommittee of ASTM Commitee D-1 on Paint, Varnish, Lacquer and Related Products. The results of this work were published in the October, 1950 ASTM Bulletin No. 169.

The work included mathematical formulas that accommodated the nonlinearity at the lower range of each cup (due to eddy current turbulence at the orifice). This permitted comparison of results between the 17 different types of cups listed above stated time minimums.

Also included in the work were the results of an industry survey on the preference of viscosity measuring devices.

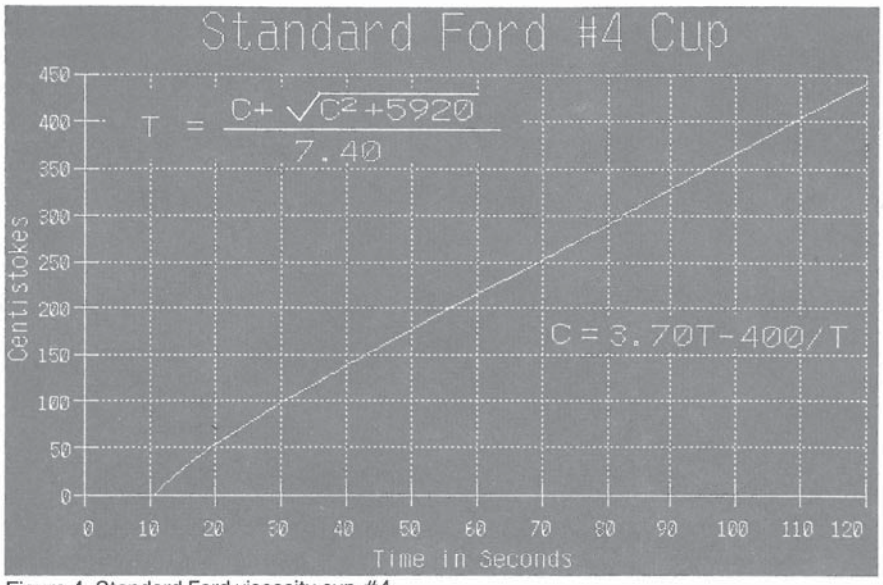

Figure 4. Standard Ford viscosity cup #4.

Where the cup type instruments were applicable, the preference was heavily weighted in favor of the Ford viscosity cup series.

An ASTM Standard Method of Test for Viscosity of Paints, Varnishes and Lacquers by Ford viscosity cups was adopted in 1954. It is carried under ASTM designation D 1200. There was a minor revision to this method in 1958, with reapproval in 1965.

In D 1200-58 (1965), the dimensions of the cup and the orifice were shown. A graph replaced the flow formula that was developed in the earlier work. The graph related viscosity in stokes to time in seconds for the numbers 2, 3 and 4 Ford viscosity cups. The lines in the graph for cup numbers 3 and 4 were in close conformity to the earlier work, except near the lower useable range.

There was a change in the ASTM method in 1970, and it was published in following standards as D 1200-70. The dimensions of the series were changed to metric, but there was no intended change in actual magnitude. The change with probably the greatest effect was the reduction to quarter size of the graph of "Standard Viscosity Curves for Ford Cups."

It seems that a flow formula included in the appendix of D 1200-70 was intended to match the curves in the graph of D 1200-58. In this attempt, there was a greater divergence with respect to the work published in 1950.

There is one major supplier of the Ford cup series that has adhered to its definition as detailed in the 1950 work. Others meet the definition of D 1200-70. It is important to analyze the magnitude of the difference.

In D 1200-70, the time range recommended for the numbers 3 and 4 cups is 20 to 100 seconds. It is 40 to 100 seconds for the number 2 cup. A major supplier recommends a minimum of 39 seconds for the number 2, 27 seconds for the number 3 and 23 seconds for the number 4. By imposing these higher minimums, there is less difference between the cups of all suppliers. The percent difference between the published 1950 work (D 1200-58 for cup #2) and D 1200-70 is as follows:

Seconds	Cup #2	Cup #3	Cup #4
20		242	7
25		44	0
30		15	2
35	10	4	3
40	3	2	5
60	3	9	3
80	2	10	2
100	4	10	2

The new standard Ford Cup Series

A new design in viscosity cups combines the desirable features and eliminates the undesirable ones. To have maximum use, however, the new design should not add to the present lengthy list. Rather, it should replace one or more of the most popular cups. Prototypes have been tested and the advantages have been confirmed:

- A mathematical formula has been developed for each cup in the series. The formulas relate viscosity in centistokes to time in seconds.
- The flow formula for each cup in the series has been selected. It provides results that are as close as possible to an average of other similar Ford cups.
- The flow formula (as applied to the physical dimensions of each cup in the series) has been confirmed. Using standard oils (traceable to National Bureau of Standards) and other liquids, the formula covers from zero viscosity to a viscosity proportional to 150 seconds flow time.
- Cup dimensions influencing flow time conform to those specified in ASTM D 1200-70 (except for very minor adjustment of orifice diameter).
- Weight of the cup has been reduced by 20 percent. This also reduces the influence of cup temperature on the temperature of the material being measured.
- The top interior of the orifice has been reshaped. It now provides a sharper break in the stream as the cup empties.
- The taper fit of the orifice eliminates hard-to-clean areas.
- The orifice is readily removable and inserted without tools.
- Design of the bottom of the cup gives increased protection to the orifice.
- A deepened drip well accommodates more material.
- A tripod support enhances the use of the cup.

Graphical representation of the flow characteristics for each of the three cups of the series are shown in Figures 2, 3 and 4. Also shown are the applicable mathematical formulas. In the formulas, "T" is time in seconds and "C" is viscosity in centistokes.

In each of the Figures the curve starts at zero viscosity. At very low levels, at least a half of the time value is due to turbulence at the orifice. The minimum seconds for each cup in actual practice should be 150 percent of the seconds shown at zero viscosity or:

Cup number	Minimum seconds
2	37
3	23
4	16

The maximum seconds shown in the Figures relating seconds to centistokes are 120. This is to emphasize the shape of the curve at lower time intervals. The cups have been checked with standard oils as high as 150 seconds. The results have been just as accurate as those at 120 seconds. Cups can be used as high as 150 seconds on materials that display a steady rate of discharge from the orifice. ■