

# Reference: Polymer Properties

## Viscosity

### Viscosity Terms

$\eta_{rel}$  is determined by the ratio  $t/t_0$ , where (t) is the outflow time of a given volume of solution and ( $t_0$ ) is the outflow time of the equivalent volume of pure solvent. Values are commonly determined with a capillary viscometer. Other viscosity terms are defined in Table I.

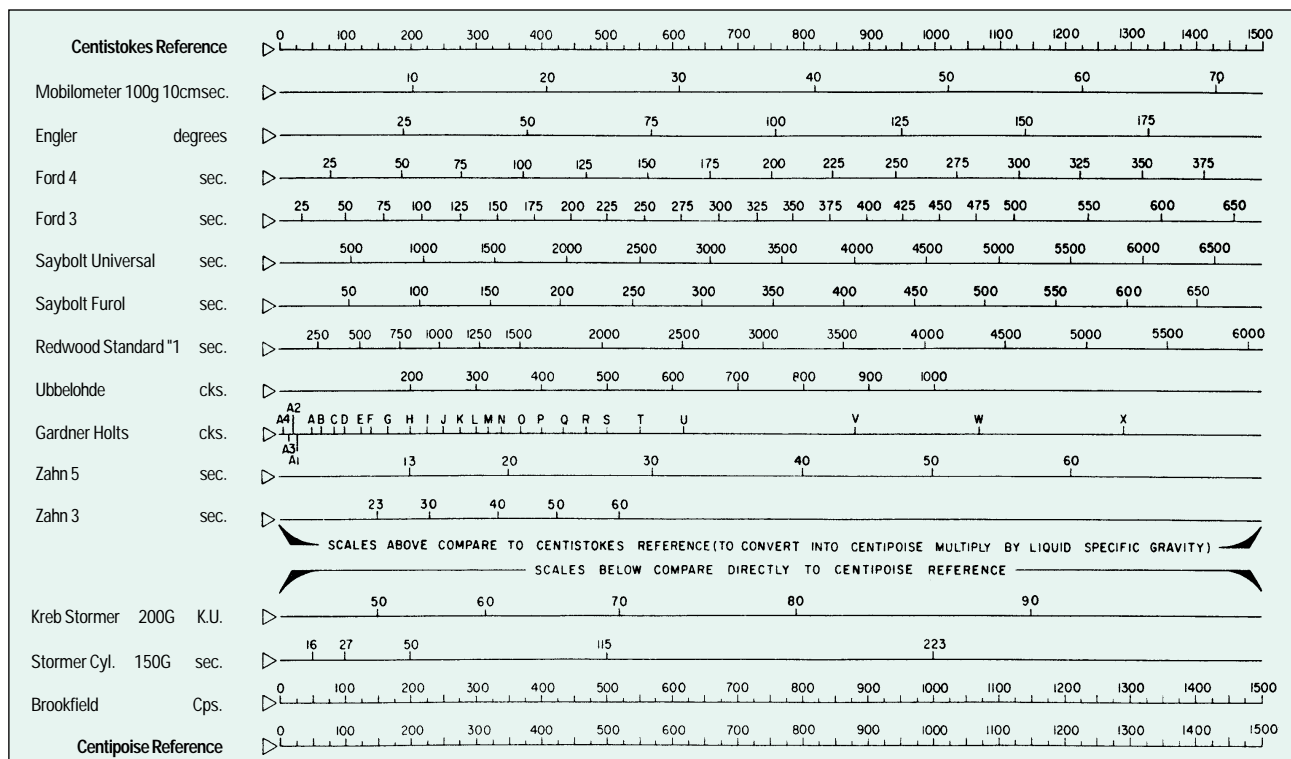
**Table I: Definition of Viscosity Terms**

IUPAC Name	Common Name	Definition	Symbol	Units
Viscosity ratio	Relative viscosity	$\eta/\eta_0$	$\eta_{rel}$	dimensionless
Specific viscosity	Specific viscosity	$\eta/\eta_0 - 1$	$\eta_{sp}$	dimensionless
Viscosity number	Reduced viscosity	$\eta_{sp}/c$	$\eta_{red}$	deciliter/gram
Logarithmic viscosity number	Inherent viscosity	$\ln \eta_{rel}/c$	$\eta_{inh}$	deciliter/gram
Limiting viscosity number	Intrinsic viscosity	$\lim_{c \rightarrow 0} (\eta_{sp}/c)$ $\lim_{c \rightarrow 0} (\ln \eta_{rel}/c)$	$[\eta]$	deciliter/gram
Absolute viscosity			P Pa · s	Poise (dynes · s/cm) Pascal · second (Newton · s/m <sup>2</sup> )
Kinematic Viscosity			St	Stokes (m <sup>2</sup> /s)

Conversion factor:  $\eta(\text{Poise}) = \eta(\text{Stoke}) \times \text{density (g/cm}^3\text{)}$

### Viscometer Comparison for NEWTONIAN Liquids

The chart<sup>1</sup> below is intended to be an aid in comparing viscometer measurements of Newtonian liquids by referencing to absolute and kinematic viscosity.



<sup>1</sup> Reprinted with permission from Brookfield Engineering Laboratories, Inc., Stoughton, MA, U.S.A.

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## Viscosity (continued)

### Viscosity - Molecular Weight Relationships

#### Mark-Houwink-Sakurada Equation:

$$[\eta] = KM^a \text{..... Eq. 1}$$

where:  $[\eta]$  = intrinsic viscosity,

K and a = constants, dependent on the polymer, solvent, and temperature

Caution must be exercised in applying this relationship since the K value is greatly influenced by the molecular weight distribution of the polymer sample used in the determination.

Within a given series of polymer homologs,  $[\eta]$  increases with the molecular weight M. This is illustrated in Table I for poly(dimethylsiloxane).

The molecular weight of polymers such as poly(vinyl chloride) and poly(vinyl pyrrolidone) are often reported in terms of the Fikentscher K-value, derived from a solution viscosity (see [Glossary under K-value](#)) which should not be confused with the constant K of the Mark-Houwink-Sakurada equation (1). The relationship between the intrinsic viscosity, K-value, and approximate molecular weight is illustrated in Tables II and III for PVC and PVP, respectively.

**Table I:  $[\eta]$  -  $M_w$  relationship for poly(dimethylsiloxane), trimethylsilyl terminated<sup>1</sup>**

Viscosity, cSt @ 25°C	$M_w$
1.0	240
2.0	400
5.0	800
10	1,300
50	4,000
200	9,500
500	17,000
1000	28,000
10,000	63,000
100,000	140,000

<sup>1</sup>  $M_w$  values are approximate and should be used as a guide for the estimated molecular weight.

**Table II: Relationship between intrinsic viscosity, K-value and approximate molecular weight for poly(vinyl chloride)<sup>2</sup>**

Intrinsic viscosity, $[\eta]$	K Value 1% in Cyclohexanone	$M_n$	$M_w$
0.52	50	20,000	40,000
0.67	57	27,500	55,000
0.92	67	41,000	82,500
1.08	72	50,000	101,000
1.30	79	62,500	123,500
1.60	87	81,000	168,000

<sup>2</sup> Perkins, G.G.A. et.al., *J. of Vinyl Technology*, **1993**, 108,15.

**Table III: Relationship of viscosity, K-Value, and approximate molecular weight for poly(vinylpyrrolidone) (PVP)<sup>3</sup>**

Viscosity in water cSt (%PVP)	K Value range	$M_n$	$M_w$
7(20)	13-19	10,000	12,000
25(20)	26-34	40,000	55,000
50(10)	50-62	220,000	400,000
400(10)	80-100	630,000	1,280,000
7000(10)	115-125	1,450,000	2,800,000

<sup>3</sup> GAF(ISP) Technical Bulletin 2302-203 SM-1290, "PVP polyvinylpyrrolidone Polymers", **1990**.