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From lab to production,
providing a window into the process

The ViscoSensor On-Line Rheometer

Operation and Calculations

Direct MFR (Constant Stress) Mode

(System Run Under Pressure Control)

Melt Flow Rate (g/10 min.) =

$$MFR = 10\,V\,S\,d\,(C)\left[\frac{2.0955\,mm}{D_c}\right]^3$$

Where:

V=Pump volume (cc/rev)
S=Pump speed (rpm)
d=Polymer melt density (g/cc)
D_c=Capillary diameter used (mm)
C=Correlation factor

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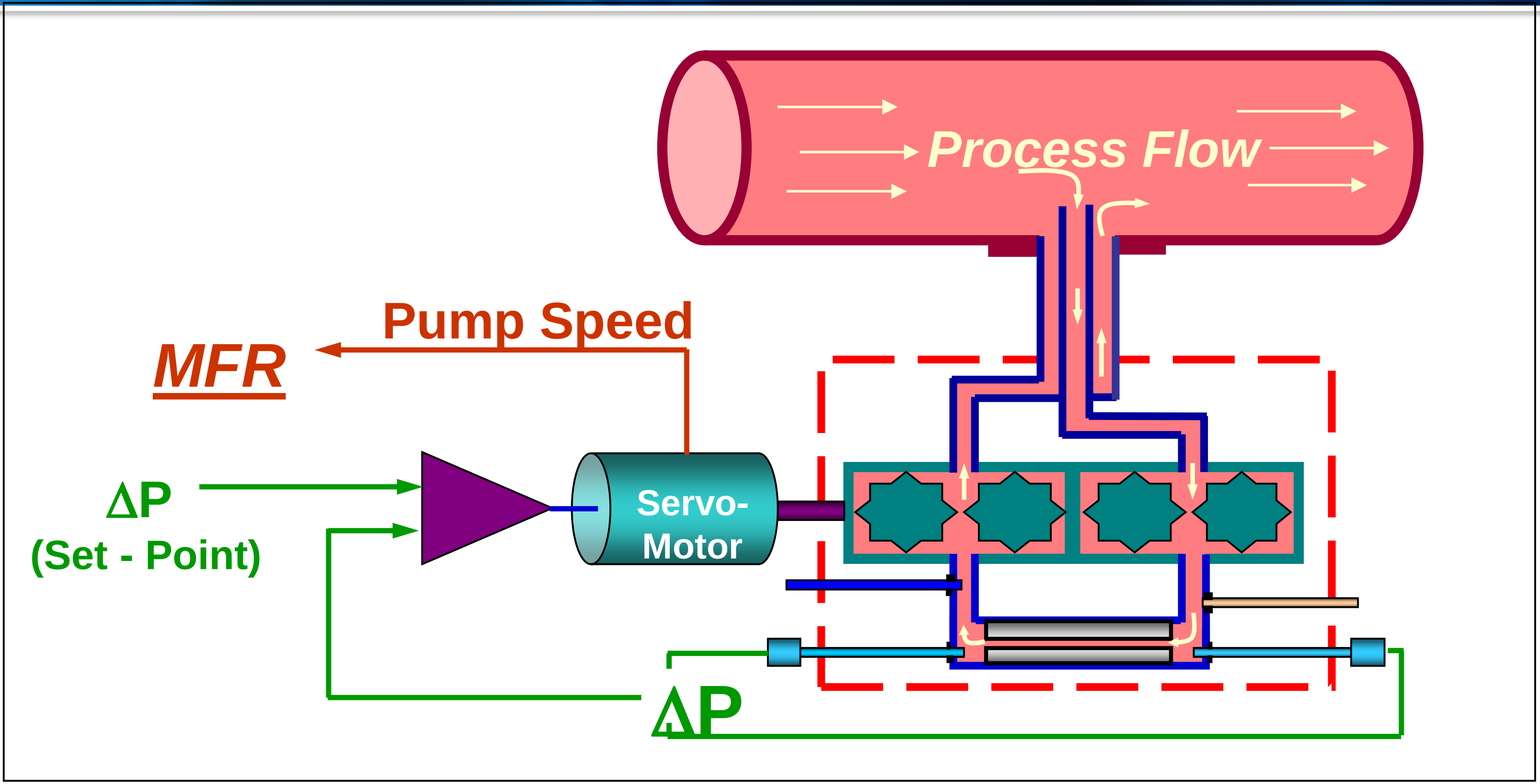
Direct MFR (Constant Stress) Mode

ViscoSensor Configuration for Operation Under Pressure Control



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Direct MFR (Constant Stress) Mode – Part 1

The melt pump is run at a speed sufficient to keep a constant pressure drop across the capillary die.

ΔP defined by conditions specified in ASTM D-1238.

ΔP is calculated from the expression: $\Delta P = 4\tau_{w,ASTM}(L_c/D_c)$

Where $\tau_{w,ASTM}$ = Shear stress generated in the ASTM test.

- **For the standard ASTM Test, D = 2.0955 mm and L/D = 3.818, the pressure generated by a 2.16 Kg load = 43.25 psi.**

- **In the ViscoSensor when, for example, D = 2.0 mm and L/D = 15 the pressure drop required to simulate a 2.16 Kg load = 169.9 psi.**

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Direct MFR (Constant Stress) Mode – Part 2

The RPM of the pump (S), required to maintain the correct pressure drop, the pump cc flow / rev (V), the die diameter (D) in mm, and the polymer melt density (d) at the test temperature (g/cc) are used to calculate the melt flow rate from:

Example:

$$MFR = 10\, V\, S\, d\, (C)\left[\frac{2.0955\ mm}{D_c}\right]^3$$

When V= 0.3 cc/rev, D_c= 2.0 mm, d = 0.76 g/cc and a pump speed of 7.43 rpm is required to maintain a pressure of 169.9 psi:

MFR = 10(0.3cc/rev) (7.43 rev/min)(0.76 g/cc) (1) [2.0955 mm/2.0 mm]^3 =

19.48 g/10 min.

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Direct MFR (Constant Stress) Mode – Part 3

C is the correlation factor that corrects the MFR of the ViscoSensor to that measured in the laboratory.

$$C = \frac{(MFR)_{Lab}}{(MFR)_{VS}}$$

Example:

For the measurement shown above, if the laboratory obtains an MFR value of 18.00 g/10 min, then:

C = (18.00) / (19.48) = **0.924**

Viscosity (Constant Rate) Mode

(System Run Under Pump Speed Control)

Apparent Viscosity (Pa-s) =

$$\eta_a = \frac{10.15(\Delta P)D^3}{V\,S(L/D)}$$

Where:

V= Pump volume (cc/rev)
S= Pump speed (rpm)
ΔP= $P_2 - P_1$ = Pressure drop
across capillary (psi).
D= Capillary diameter (mm)
L= Capillary length (mm)

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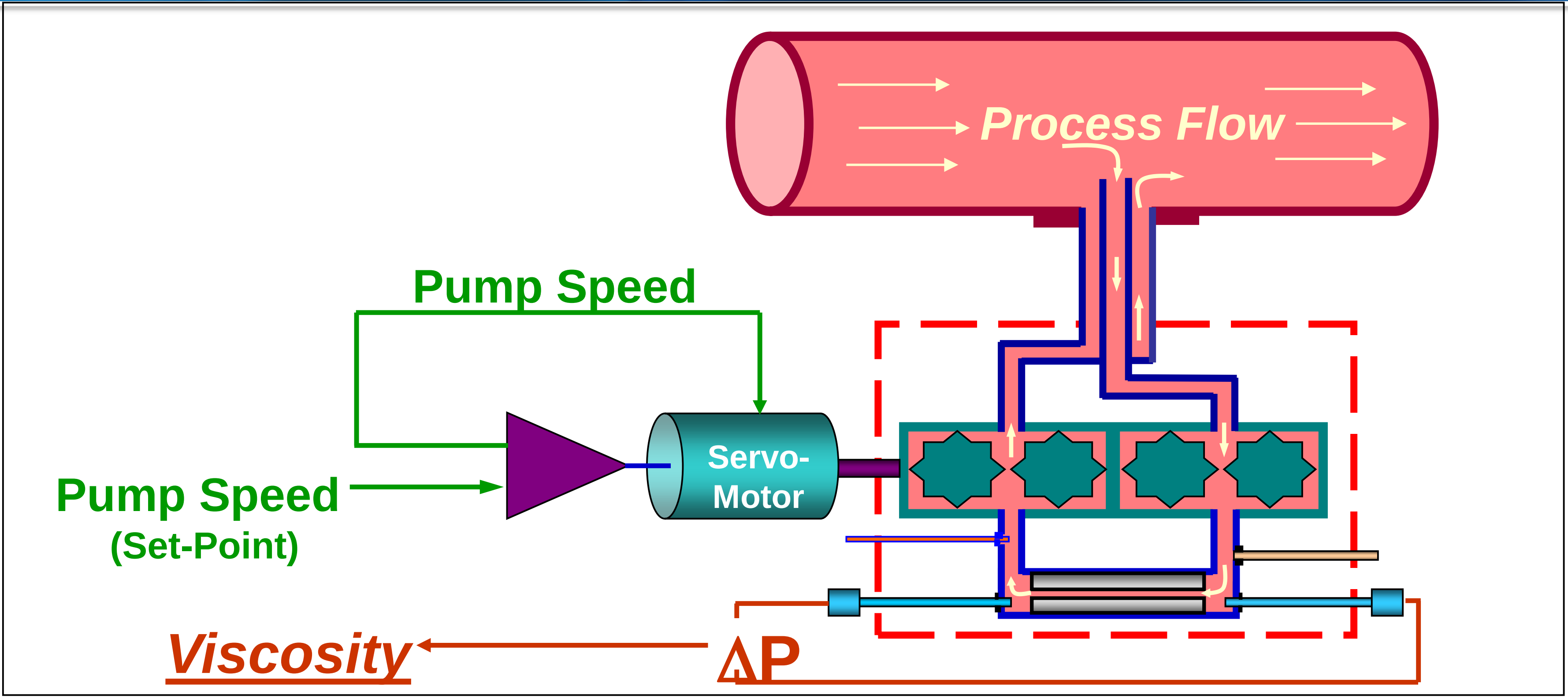
Viscosity (Constant Rate) Mode

ViscoSensor Configuration for Operation Under Pump Speed Control



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Viscosity (Constant Rate) Mode

The melt pump is run at a constant speed (rpm) to produce a constant shear rate.

Shear Rate (sec^{-1}) = $$\dot{\gamma} = \frac{169.76\,(V\ S)}{D_c^3}$$

The shear rate may be changed by changing the pump speed or the diameter (D) of the die.

The pressure drop across the capillary is measured to determine the shear stress.

Shear Stress (Pa) = $$\tau_w = \frac{\Delta P\, D_c}{4L_c} = \frac{1723.69\,(\Delta P)}{(L_c/D_c)}$$

The apparent viscosity is determined by dividing the shear stress by the shear rate.

Viscosity (Pa-s) = $$\eta_a = \frac{\tau_w}{\dot{\gamma}} = \frac{10.15\,(\Delta P)\,D_c^3}{V\,S\,(L_c/D_c)}$$

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Viscosity (Constant Rate) Mode

Example Calculation:

When: **Pump Volume V = 0.3 cc / rev**

Die Diameter D = 2.0 mm

Die Length L = 30.0 mm

and operating the pump at a rate of 30 rpm produces a ΔP of 550 psi,

then:

Shear Rate = 169.76(0.3)(30)/ $(2)^3$ = **191 sec^{-1}.**

Shear Stress = 1723.69 (550) / (30 / 2) = **63202 Pa**

Viscosity = 10.15(550)$(2)^3$/ (0.3)(30)(30/2) = **331 Pa-s**