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# Improved Processing of Thermoplastics and Thermoplastic Elastomers

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## INTRODUCTION

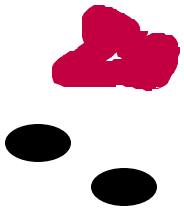
The use of additives to improve the processing characteristics of all types of polymer systems is growing in order to meet the wide ranging and ever expanding requirements of processors and end users.

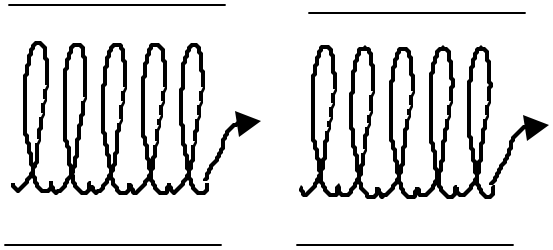
This presentation will serve to define and describe the types and functions of processing additives and their fit into the compounding and processing markets.

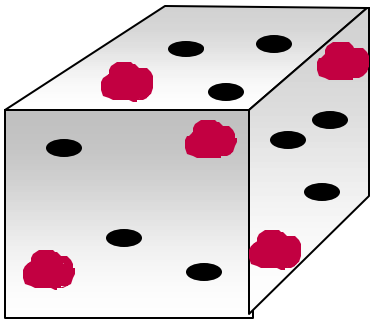
# Processing

## Thermoplastics and Rubber are Similar

| Raw Materials | | Process | Part |
|---|---|---|---|
| Polymer(s) | Fillers<br>Pigments<br>Additives | Deformation<br>Rate<br>Amount | Cooled or<br>Cured |







## EPDM WINDOW CHANNEL COMPOUND FORMULATION:

| INGREDIENT | PHR |
|---|---|
| EPDM | 100 |
| N774 Carbon Black | 100 |
| Mineral Oil | 50 |
| Polyethylene Wax | 5 |
| Zinc Oxide | 5 |
| Stearic Acid | 1 |
| TMTD | 1 |
| Methyl Zimate | 3 |
| Ethyl Cadmate | 1 |
| Sulfur | 1 |
| Calcium Oxide (80%) | 1 |
| **Totals** | 277 |

## TPV COMPOUND FORMULATION (EXAMPLE):

| INGREDIENT | PHR |
|---|---|
| EP Rubber | 200 |
| Polypropylene/Polyethylene | 50 |
| Mineral Oil | 30 |
| Talc | 15 |
| Crosslinking Resin | 6 |
| Stanous Chloride Dihydrate | 1.5 |
| Zinc Oxide | 4 |
| Zinc Stearate | 1.5 |
| Antioxidant | 1.5 |
| **TOTAL** | **309.5** |

## PVC COMPOUND FORMULATIONS (EXAMPLE):

Rigid Exterior Application

| INGREDIENT | PHR |
|---|---|
| PVC Resin | 100 |
| Impact Modifier | 5 |
| Calcium Carbonate | 12 |
| Tin Stabilizer | 1 |
| Calcium Stearate | 1.2 |
| Acrylic Process Aid | 0.5 |
| Paraffin Wax | 1.1 |
| Oxidized PE Wax | 0.2 |
| Titanium Dioxide | 0.3 |
| **TOTAL** | **121.3** |

Flexible Application

| INGREDIENT | PHR |
|---|---|
| PVC Resin | 100 |
| Impact Modifier | 5 |
| DOP Plasticizer | 25 |
| Epoxy Tallate | 3 |
| Calcium/Zinc Stabilizer | 2 |
| Stearic Acid | 0.4 |
| Acrylic Process Aid | 0.5 |
| Calcium Carbonate | 3 |
| **TOTAL** | **121.3** |

# Types and Growth Rates of Plastic Additives

1998 - 2003

| High Growth (6-7%/yr.) | Medium Growth (4-5%/yr.) | Lowest Growth (<4%/yr.) |
|---|---|---|
| ***Coupling Agents*** | Antiblocking Agents | Biocides |
| Light Stabilizers | Antioxidants | Plasticizers |
| Nucleating/Clarifying Agents | Antistats | |
| | Chemical Blowing Agents | |
| | Flame Retardants | |
| | Heat Stabilizers | |
| | Impact Modifiers/***Process Aids*** | |
| | ***Lubricants/Mold Release Agents*** | |
| | Organic Peroxides | |
| | Slip Agents | |

**SOURCE: TownsendTarnell Inc.**

# Consumption of Plastic Additives

1998

| Region | Consumption, kg | Value, $ |
|---|---|---|
| North America | 2.16 Billion | 4.1 Billion |
| Europe | 1.93 Billion | 3.8 Billion |
| Asia-Pacific | 2.70 Billion | 5.3 Billion |
| ROW | 0.92 Billion | 1.8 Billion |
| **TOTALS** | ***7.7 Billion*** | ***15 Billion*** |

**SOURCE: TownsendTarnell Inc.**

## EFFECT MECHANISMS OF THE ADDITIVES:

- Tribology
  - The science of the mechanisms of friction, lubrication, and wear of interacting surfaces that are in relative motion

- Tribological Functions
  - Adhesive
  - Lubricant
  - Surfactant

# EFFECT MECHANISMS OF THE ADDITIVES:

- Tribological
  - Adhesives
    - Increased interfacial forces created by surface attachment
    - Increase energy required to break adhesive bonds causing increased shear
  - Lubricants
    - Function to minimize the frictional forces between moving surfaces
    - Can be divided into internal and external
    - Internal is polymer:polymer, polymer:filler interaction
    - External is polymer:hot metal, filler:hot metal interaction
  - Surfactants
    - Create a surface active film via polar and non-polar ends
    - Polar end absorbs/bonds to a surface
    - Wetting of the filler allows for improved low energy dispersion
    - Similar to lubricants effect

# DIFFERENCES IN LUBRICANT TYPES:

Taken from PVC based terminology:

- **External**
  - Typically provide lubrication between the polymer and the metal surface of the processing equipment.
  - **Types**

    Polyethylene Homopolymers, Paraffins, Esters, Metallic Soaps, Amides, Fatty Acids and Oxidized Polyethylenes

- **Internal**
  - Typically reduce bulk viscosity by being partially compatible with the PVC, thus helping to open the polymer chain with the lubricants' soluble component, while providing intermolecular lubrication with the less soluble portion of the lubricant molecule.
  - **Types**

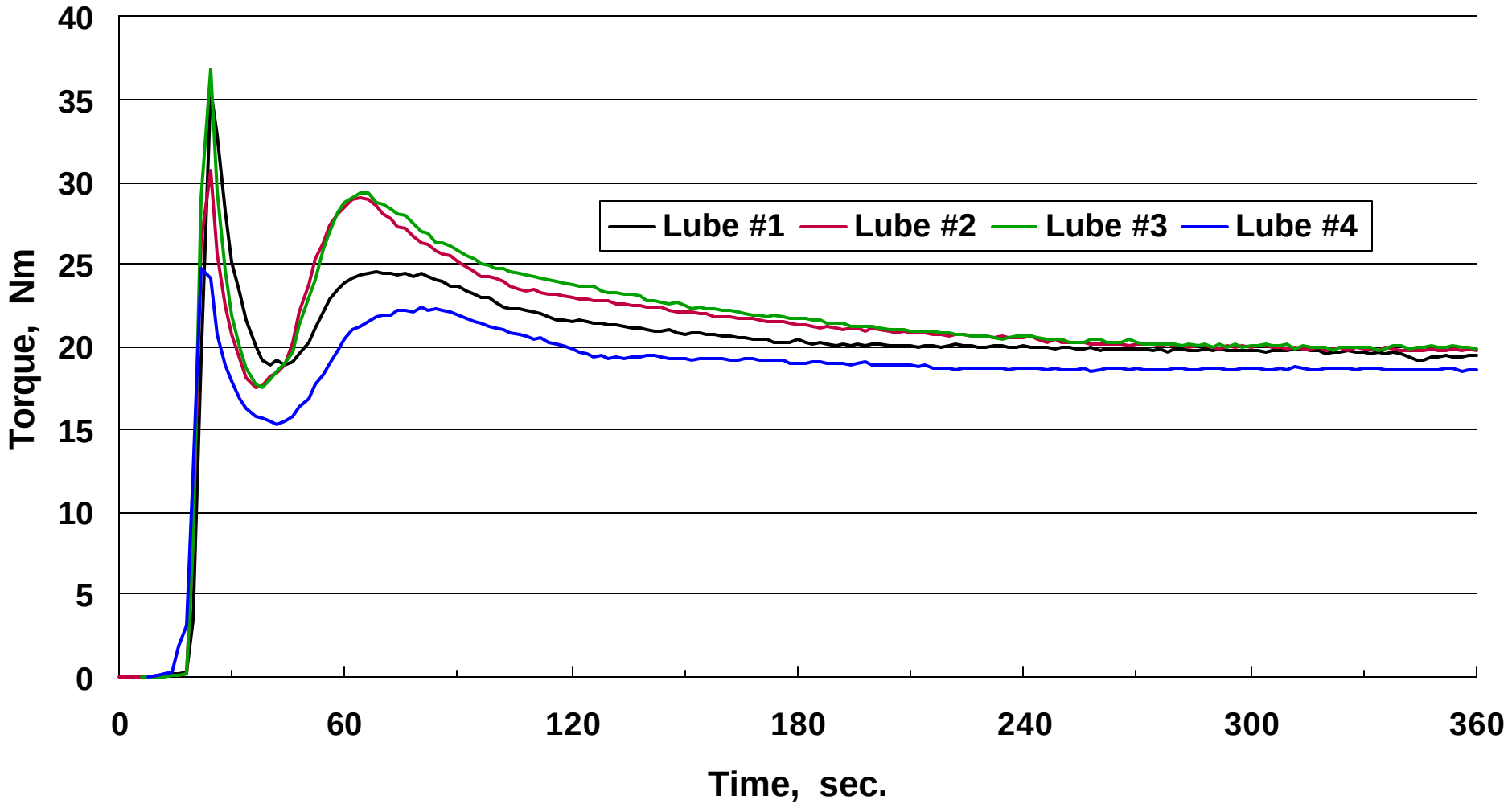
    Fatty Alcohols, Esters, EVA Waxes

# SPECIFIC EFFECTS OF LUBRICANTS

- **Internal Lubricants**
  - Promote flow
  - Exhibit good clarity
  - Promote good weld line strength
  - Minimize sink marks
  - Improve die filling
  - Reduce die swell
  - Allow increased molding speed without shear burn
  - Reduce head and back pressure
  - Do not affect paintability
  - Lower heat distortion

- **External Lubricants**
  - Provide metal release
  - Help reduce process temperature
  - Can plate out
  - Slow fusion
  - Can cause delamination
  - Can lower weld line strength
  - Can cause surging

# Effects of Lubricants on a Rigid PVC Formulation



## TYPICAL PROPERTIES OF HIGHLY FILLED COMPOUNDS:

- Increased:
  - ✓ Viscosity
  - ✓ Flexural modulus
  - ✓ Heat deflection temperature (HDT)
  - ✓ Dimensional stability

- Decreased:
  - ✓ Izod Impact
  - ✓ Mold shrinkage
  - ✓ Thermal expansion
  - ✓ Part cost

- Goals:
  - ✓ Decreased wall thickness = decreased part weight
  - ✓ Equivalent properties
  - ✓ ***Lower Cost!!!***

**BRABENDER MIXING DATA:**

40% Wood Flour Composites

| | Cont. | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| Peak Torque, Nm | 90 | 68 | 57 | 67 | 62 | 65 | 55 |
| Torque @ 2', Nm | 11 | 13 | 10 | 12 | 12 | 11 | 9 |
| Torque @ 3', Nm | 9 | 11 | 8 | 11 | 11 | 10 | 6 |
| Torque @ 4', Nm | 9 | 11 | 7 | 11 | 10 | 10 | 5 |
| Equilibrium Temp, °C | 174 | 172 | 171 | 175 | 172 | 173 | 169 |
| Metal Release Rating | + | ++++ | ++++ | +++ | +++ | +++ | ++ |

| | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|
| Peak Torque, Nm | 100 | 68 | 57 | 59 | 58 | 65 | 64 |
| Torque @ 2', Nm | 16 | 15 | 15 | 16 | 14 | 14 | 9 |
| Torque @ 3', Nm | 13 | 13 | 13 | 14 | 13 | 13 | 7 |
| Torque @ 4', Nm | 11 | 13 | 12 | 13 | 12 | 12 | 6 |
| Equilibrium Temp, °C | 184 | 181 | 180 | 181 | 180 | 179 | 171 |
| Metal Release Rating | + | +++ | ++++ | +++ | +++ | +++ | ++ |

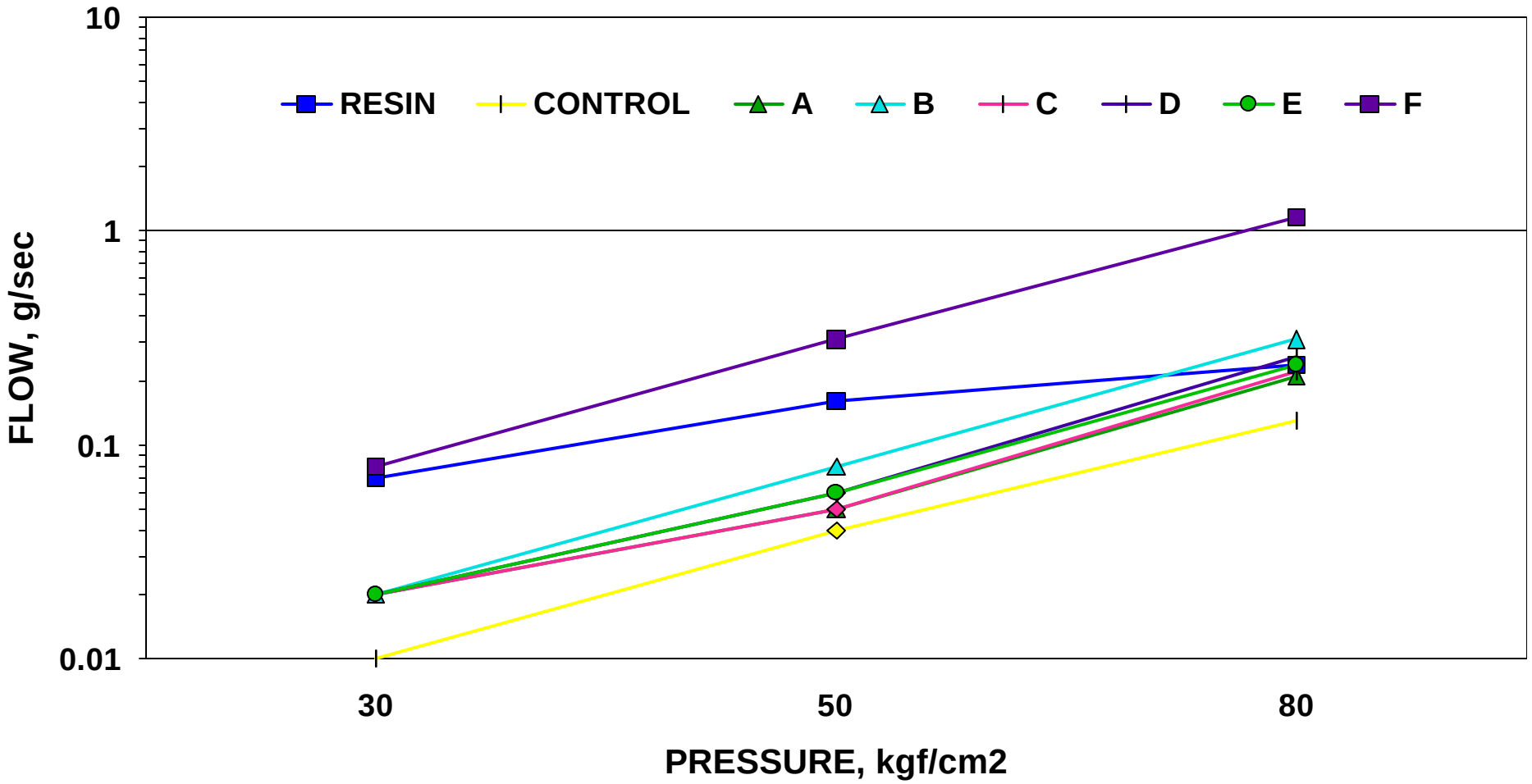
## CAPILLARY RHEOMETER DATA:

40% Wood Flour Composites comparing lubricants, adhesives and surfactants

| | Resin | Cont. | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|
| 30 kgf/cm² @ 190°C | | | | | | | | |
| Flow, g/sec | 0.07 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.08 |
| Viscosity, Pa· s | 102 | 564 | 423 | 305 | 382 | 350 | 387 | 89 |
| Shear, sec-1 | 718 | 130 | 173 | 240 | 192 | 209 | 190 | 822 |
| 50 kgf/cm² @ 190°C | | | | | | | | |
| Flow, g/sec | 0.16 | 0.04 | 0.05 | 0.08 | 0.05 | 0.06 | 0.06 | 0.31 |
| Viscosity, Pa· s | 68 | 274 | 216 | 139 | 382 | 183 | 199 | 39 |
| Shear, sec-1 | 1792 | 446 | 567 | 879 | 192 | 668 | 615 | 3126 |
| 80 kgf/cm² @ 190°C | | | | | | | | |
| Flow, g/sec | 0.24 | 0.13 | 0.21 | 0.31 | 0.22 | 0.26 | 0.24 | 1.16 |
| Viscosity, Pa· s | 79 | 152 | 90 | 62 | 89 | 74 | 82 | 17 |
| Shear, sec-1 | 2482 | 1283 | 2167 | 3146 | 2209 | 2637 | 2394 | 11770 |

# 40% WOOD FLOUR COMPOSITE RHEOLOGY

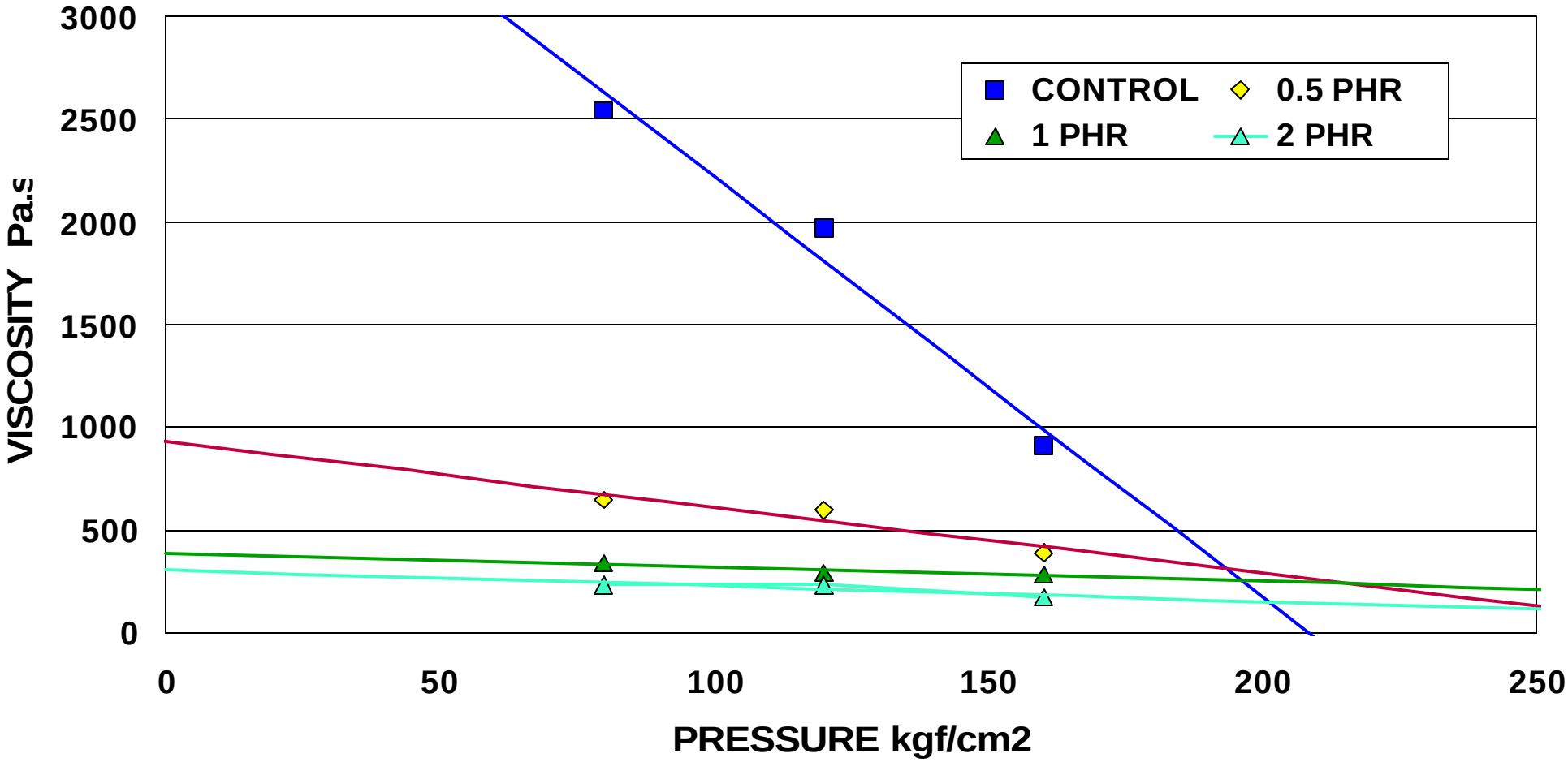
## LOG FLOW VS. PRESSURE




*Quality Additives for Performance*

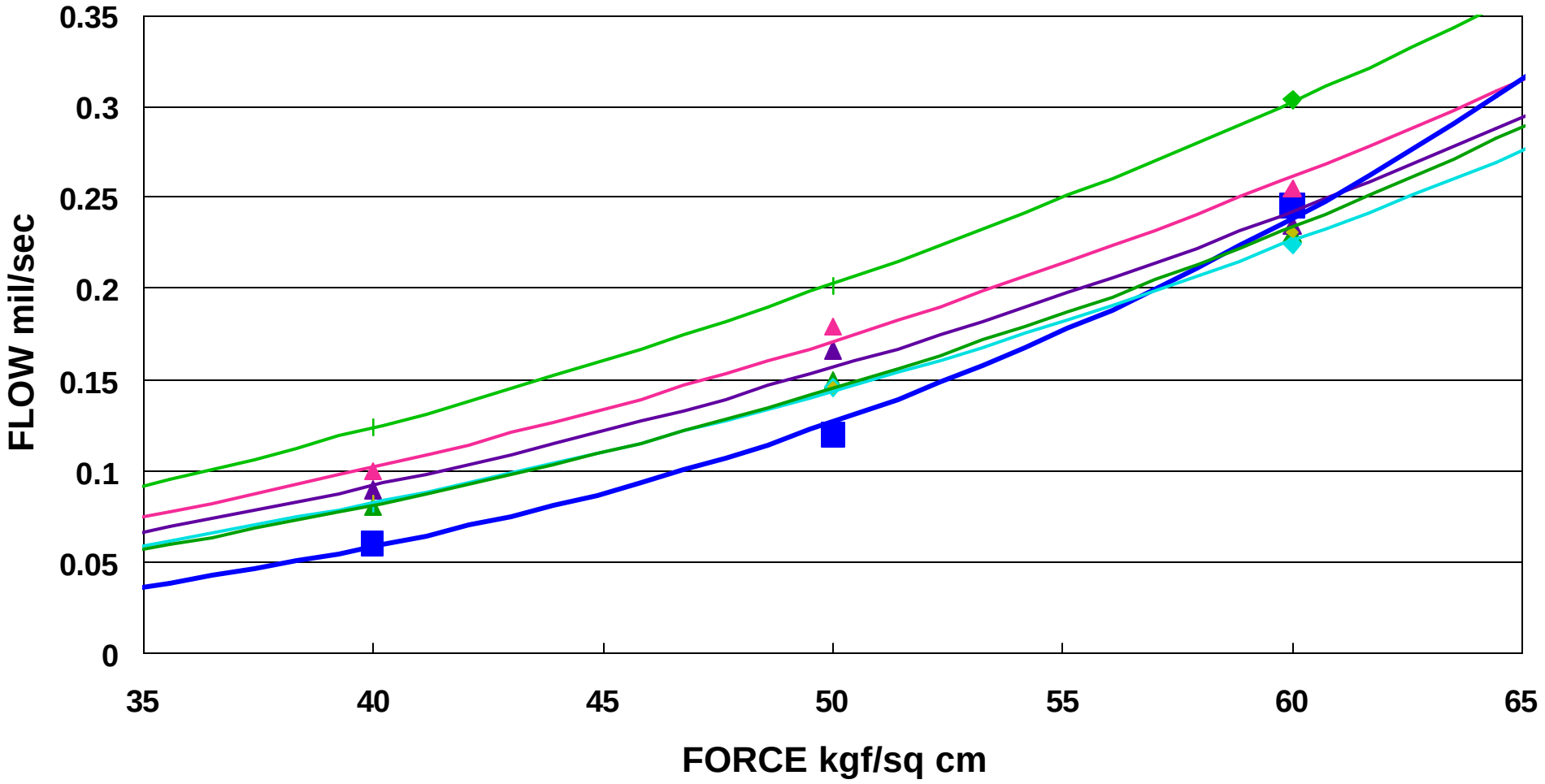
# Polycarbonate Flow Characteristics

## Non-lubricated vs. Ester-based Lubricant



# Improved Processing of Low Hardness TPV

## 35 Shore A Injection Molding Grade




*Quality Additives for Performance*

## BENEFITS/APPLICATIONS FOR IMPROVED FLOW/PROCESSING:

*Benefits:*

- ★ Thinner wall molding
- ★ Longer flow lengths
- ★ More intricate shapes/designs
- ★ Improved foamability/cell size control?

*Applications:*

- ★ Over molding for soft touch grips (e.g. appliances, toothbrush, etc.)
  - Dipped PVC plastisol replacement?
- ★ Glass/window encapsulation
- ★ Small parts
- ★ Seals, weatherstripping

## CONCLUSIONS:

- Many types of processing problems and or difficulties can be solved through the use of additives.
- Changing the processing characteristics of compounds and resins can open up windows of opportunity in many applications.
- Improved processing ***always*** leads to cost reduction.