Wire Drawing Soap Lubrication: Principles And Factors Affecting Selection

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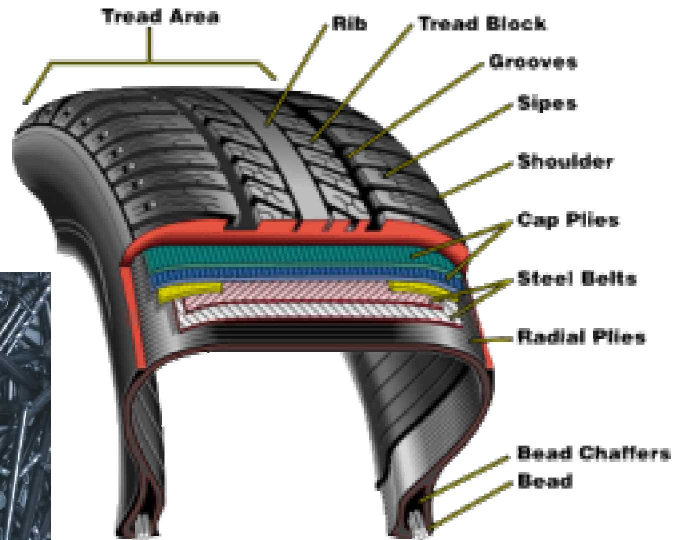
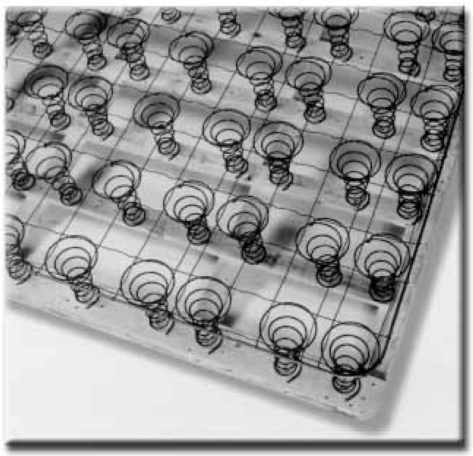
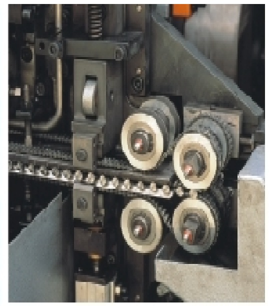
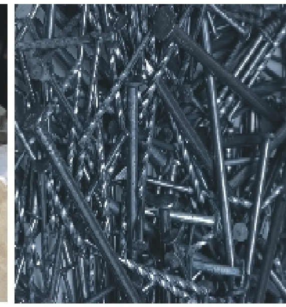
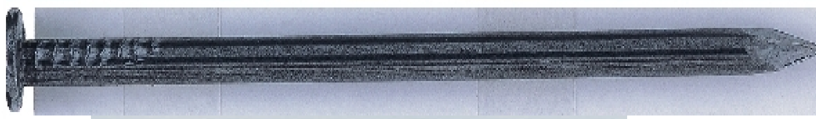
Wire Products

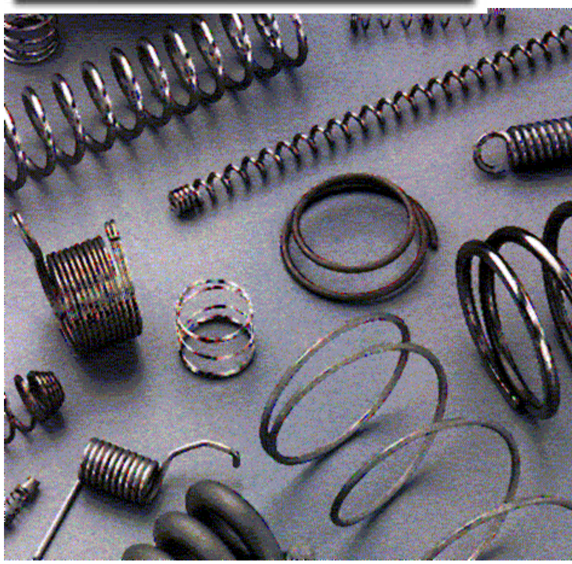


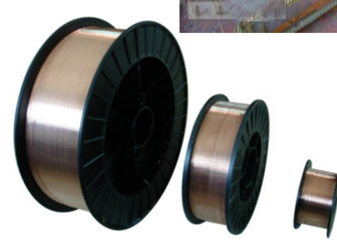












Rod: The Starting Material

The tool: Wire Drawing machines

Dry Draw Bench

Courtesy of
Lamnea Bruk, Ljusfallshammar, Sweden

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Powder: The lubricant

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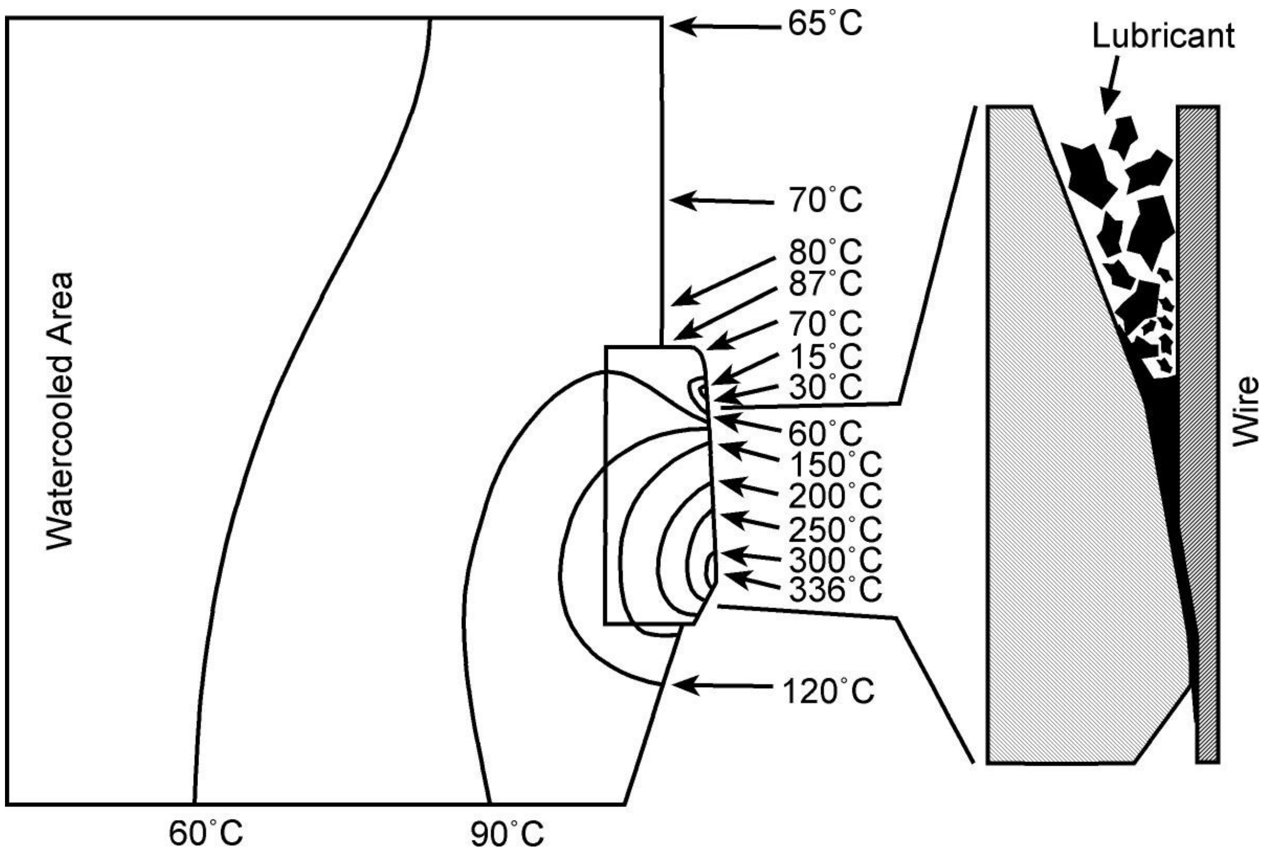
Heat Generation In Wire Drawing

HEAT GENERATED ∝ 85%

ALLOY
DRAWING SPEED
REDUCTION
ETC.

+ 15%
(FRICTIONAL HEAT)

Wire Drawing Die Temperature Profile



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Heat Generation As A Function Of Lubricant

DIE#	OBSERVED BLOCK TEMP. °C W/ LUBE(S) A	OBSERVED BLOCK TEMP. °C W/ LUBE(S) B
RIPPER	100	86
2	100	93
3	126	107
4	OBSTRUCTED VIEW	OBSTRUCTED VIEW
5	145	118
6	135	119
7	124	116
DEAD BLOCK	175	143

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Pre-coats

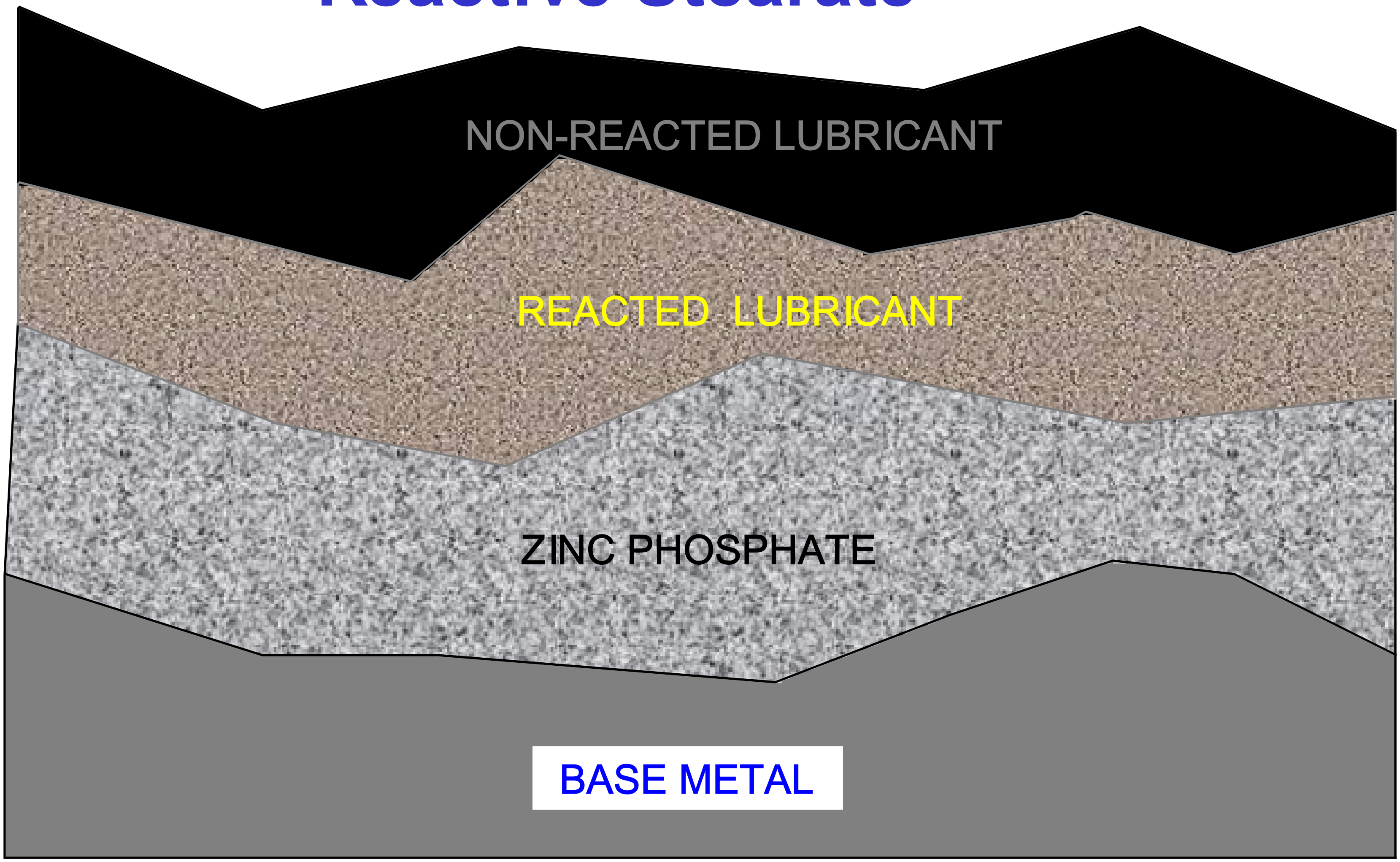
Carrier Coatings

Provides “carrier” sites for the wire drawing lubricant.

Improves the wire drawing lubricants qualities

- Viscosity
- Hydrodynamic Lubrication
- Boundary Lubrication

Zinc Phosphate With Reactive Stearate



Non-Reactive Pre-coats

<u>Formulated</u>

- Neutralizes excess pickling & zinc phosphate acid
- Contains wetting agents to improve coating uniformity
- Provides viscosity modifiers for the wire drawing lubricant
- Provides crystalline sites for additional dry drawing lubricant pickup
- Provides a physical barrier between work and tooling
- Imparts corrosion protection

Non-Reactive Pre-coats

Borax

- Neutralizes excess pickling acid
- Creates crystalline sites for additional dry drawing lubricant pickup
- Provides viscosity modifiers for the dry drawing lubricant
- Provides a physical barrier between work and tooling
- Hygroscopic

Non-Reactive Pre-coats

Lime

- Neutralizes excess pickling acid
- Creates an amorphous dry-in-place coating to aid in dry drawing lubricant pickup
- Provides viscosity modifiers for the dry drawing lubricant
- Provides a physical barrier between work and tooling
- Non-hygroscopic
- Imparts corrosion protection

Dry Drawing Lubricant Components

- Lubricant Base
- Viscosity Modifiers
  - Increase viscosity and softening point
  - Increase hydrodynamic lubrication
- Extreme Pressure Additives
  - Increase boundary lubrication
- Miscellaneous
  - Coloration (identification)
  - Thermal stability enhancement
  - Corrosion inhibition

Dry Drawing Lubricant Components

- Primary Component
  - Fatty acid soaps
- Viscosity Modifiers
  - Soda ash, lime, borax, talc, clays, waxes, etc.
- Extreme Pressure Additives
  - Sulfur, chlorine, phosphates, graphite & MoS_2
- Miscellaneous Additives
  - Dyes, antioxidants, corrosion inhibitors

Principles Of Lubrication

Lubrication Is Achieved From Two (2) Mechanisms:

1. Hydrodynamic Lubrication

2. Boundary Lubrication

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Principles Of Lubrication

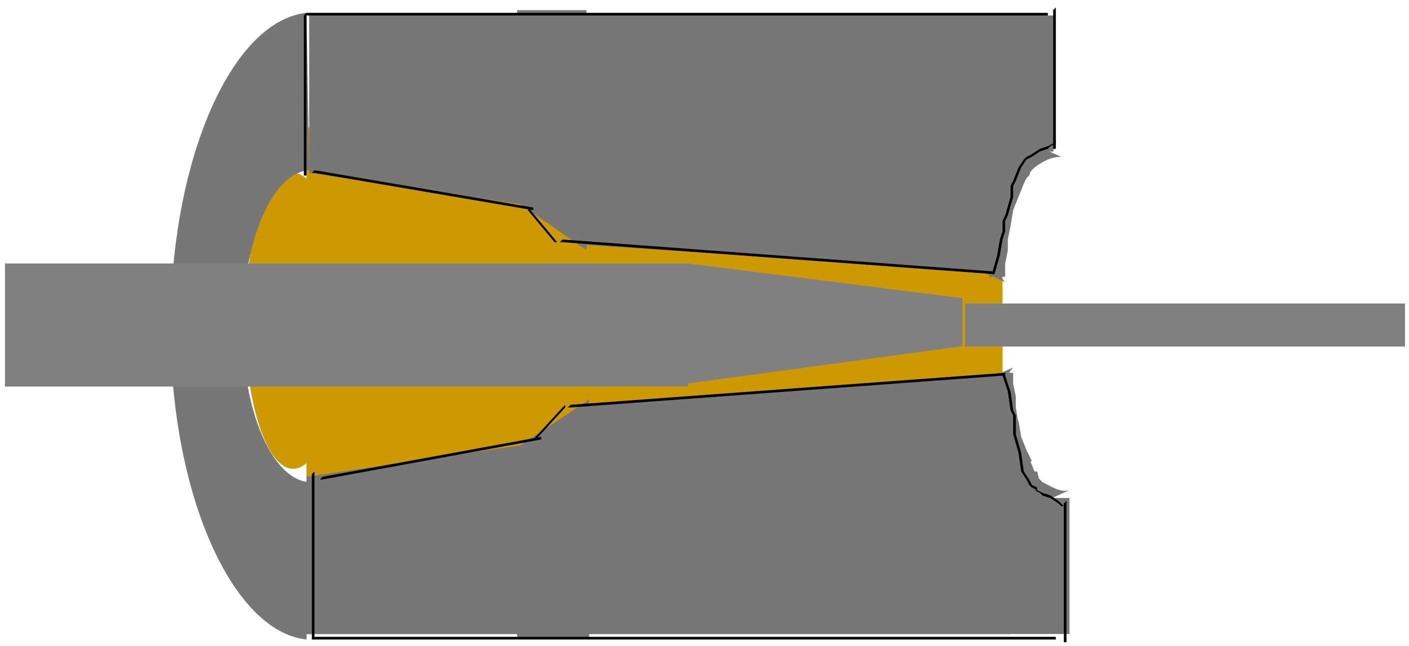
1. Hydrodynamic Lubrication[1]

- Referred to as “full film lubrication”
- Complete separation of moving components under load conditions

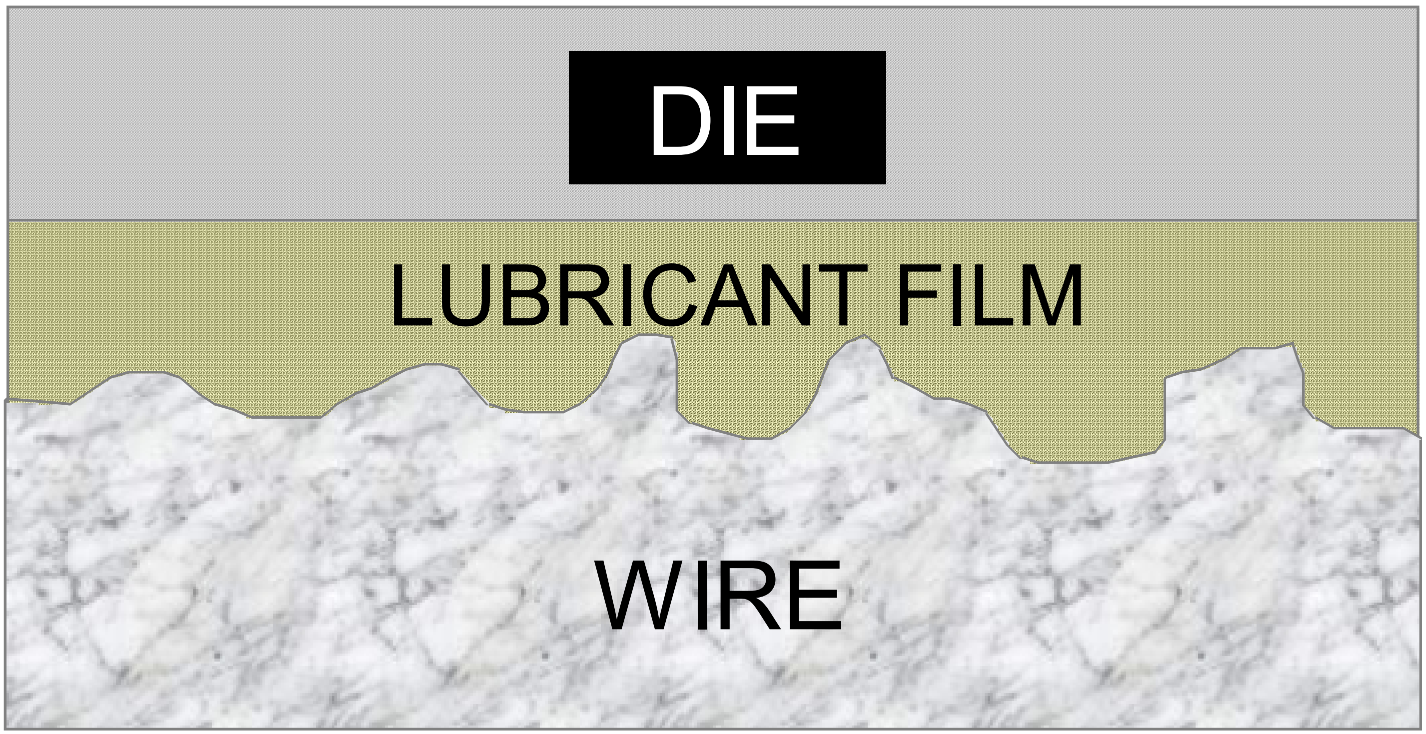
- Minimizes friction and eliminates wear

1. The Lubrication Engineers Handbook, Second Edition, Association of Iron and Steel Engineers, 1996

Hydrodynamic Lubrication



Hydrodynamic Lubrication



* Extreme Magnification for Demonstrative Purposes

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Hydrodynamic Lubrication

Ways to Improve Hydrodynamic Lubrication:

- Increase the amount of lubricant entering the die.
    - Use mechanical devices i.e., pressure dies and applicators to apply more lubricant
- Increase the viscosity at the lubricant's softening point.

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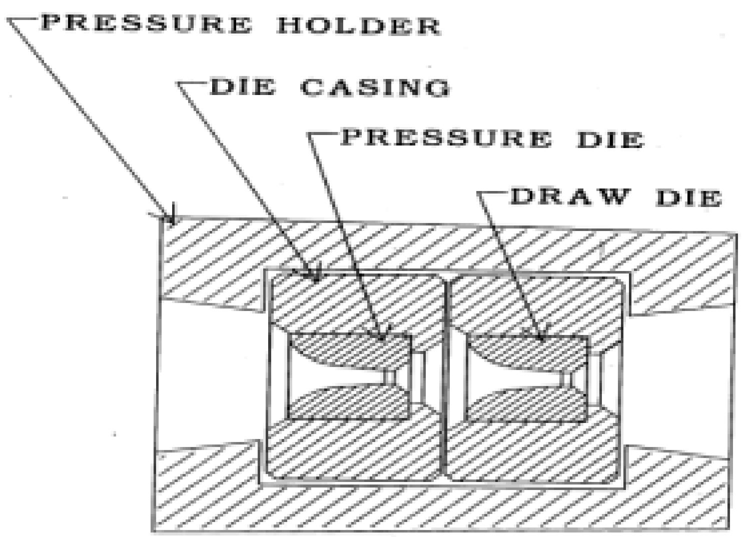
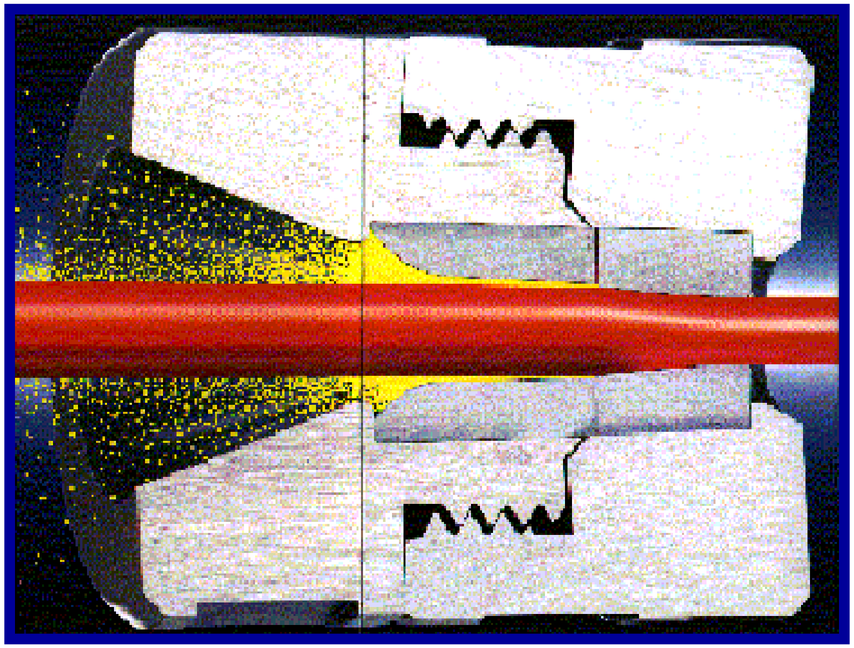
Pressure Dies



CONVENTIONAL



PARAMOUNT SYSTEM

PRESSURE DIE ON ROD BREAKDOWN – TYPICALLY 0.020 ABOVE ROD SIZE
PRESSURE DIE INTERMEDIATE WIRE – TYPICALLY 0.010 ABOVE WIRE SIZE

Lubricant Applicators

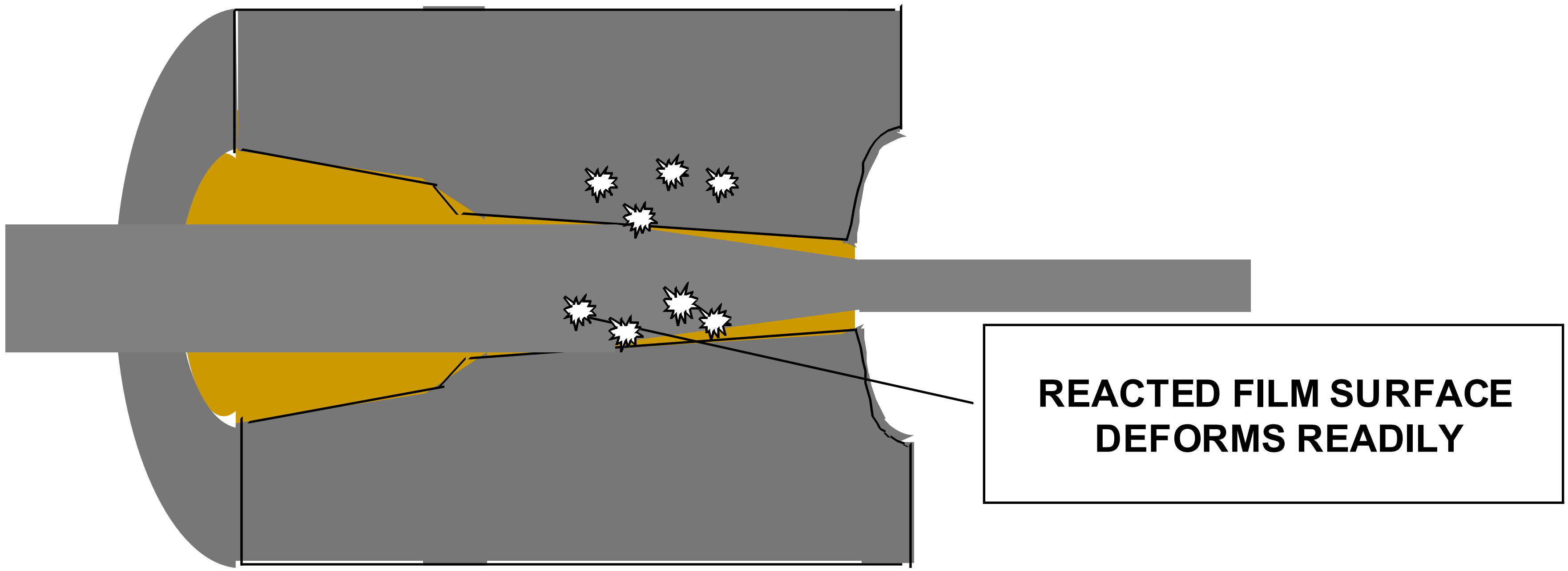
Courtesy of Wire Lab Company, Cleveland, OH

Principles Of Lubrication

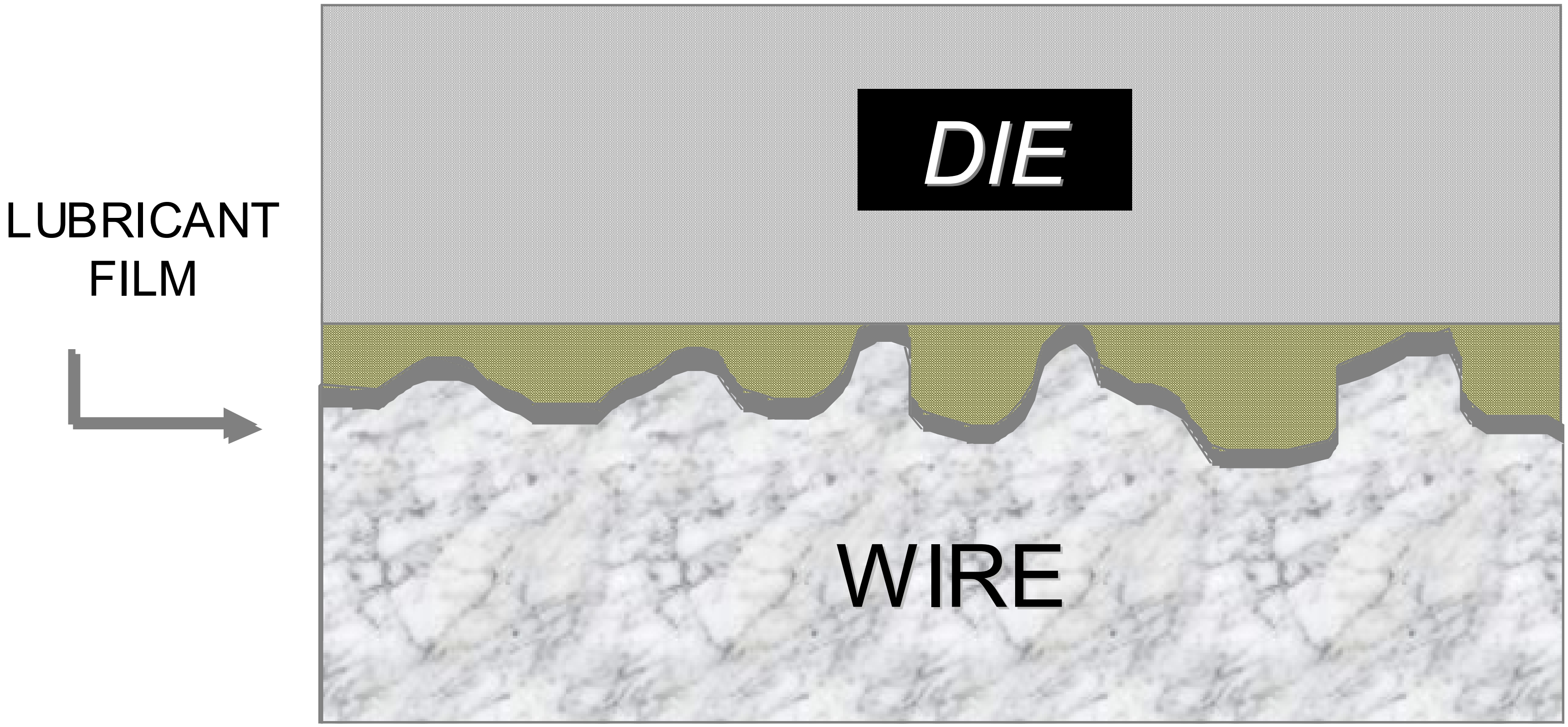
2. <u>Boundary lubrication</u>[1]
   - Required when the lubricant film is not thick enough to separate the two surfaces in relative motion to each other
   - The friction is controlled by the lubricant's chemical properties rather than it's viscosity.
   - The lubricant reacts with the wire surface to create a material that is softer than either the die or wire substrate.
     - The softer surface deforms more easily, protecting the die and wire surfaces from wear.

1. The Lubrication Engineers Handbook, Second Edition, Association of Iron and Steel Engineers, 1996

Boundary Lubrication



Boundary Lubrication



* Extreme Magnification for Demonstrative Purposes

Boundary Lubrication

- Inadequate boundary lubrication results in metal to metal contact leading to increased die wear and wire breaks
- Boundary lubrication becomes significant during:
  - Slow drawing speeds
  - Constant stopping / starting of machines
  - Poor rod or wire surface condition
- EP additives are used to promote boundary lubrication

Dry Soap Ripper Box Lubrication

Provides Approximately 85% Of The Total Lubricant Residual On The Finish Wire

- Intermediate lubricant boxes slow the depletion rate of the lubricant coating

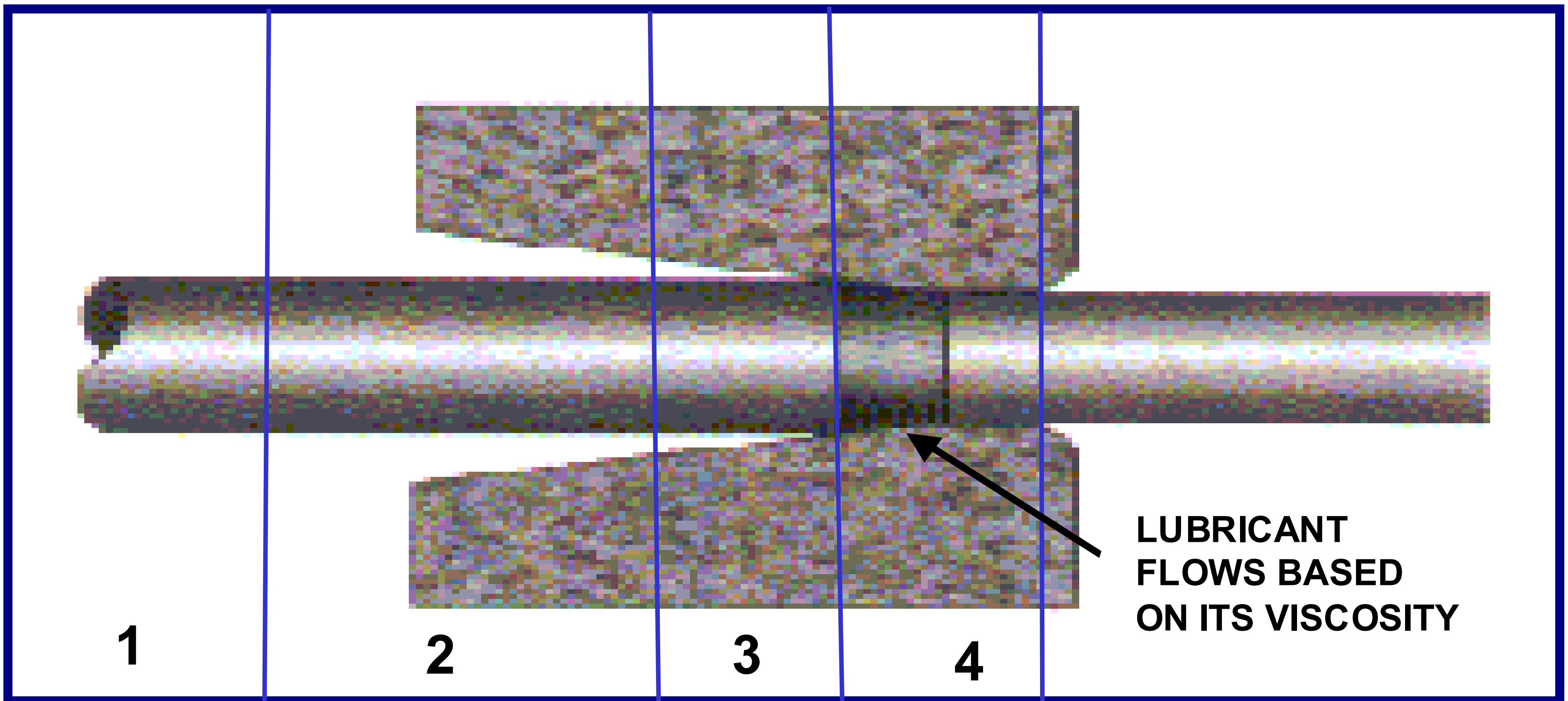
Dry Soap Ripper Box Lubrication

Coated 0.250” Low Carbon Rod Drafting 6 Holes To 0.128”

- Example 1: Soap A in ripper & box 2 / Soap B in box 3,4,5, dead block coiler
  - Coating weight 354 → 170 mg / ft^2

- Example 2: Soap A in ripper box / Soap B in box 2,3,4,5, dead block coiler
  - Coating weight 354 → 332 mg / ft^2

Dry Soap For Wire Drawing



NORMAL POWDER BEHAVIOR

LUBRICANT PULVERIZES – FLOWS INTO THE DIE

LUBRICANT TRANSFORMS INTO A PLASTIC LIKE STATE

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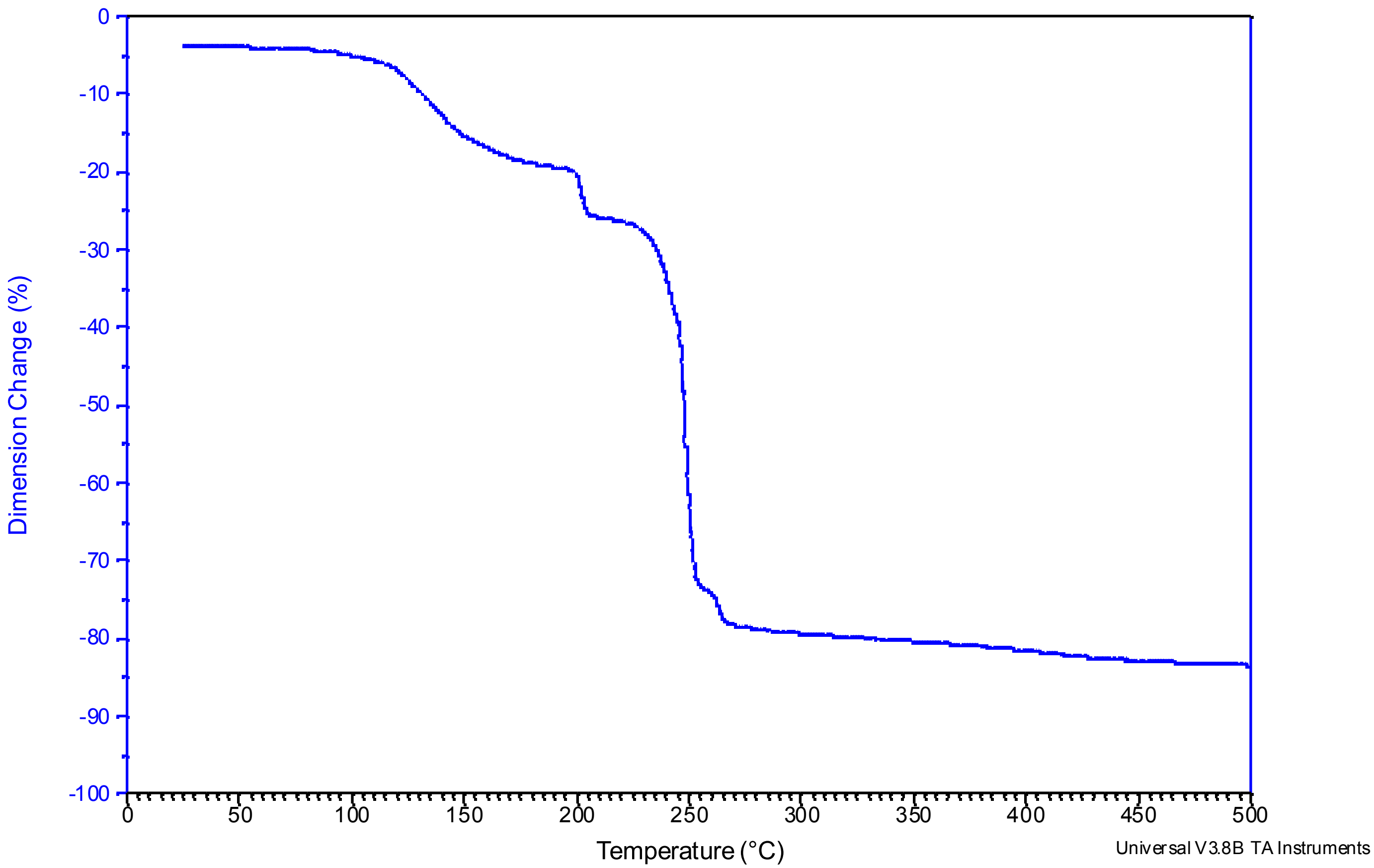
Dry Soap Softening Point Definition

The temperature range at which the lubricant soap transforms from a rigid or solid state to a viscous, elasticized state when a light force is applied to the lubricant particles.

- Depending on the chemistry used, soaps with softening points in the range of 110 - 260^{o}C are formed.

Dry Soap Softening Point Definition



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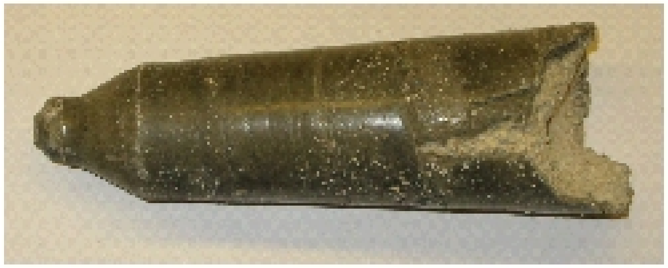
Temperature Effects On Powdered Lubricants

Temperatures Too High

Softening Point Too Low



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Temperature Effects On Powdered Lubricants

Temperatures Too Low

Softening Point Too High

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Dry Soap Classification

Titer? Richness / Leanness? Solubility?

- High titer, rich, soluble soap
- Low titer, lean, insoluble soap

Dry Soap Classification

Dry Wire Drawing Soaps Are Classified By Their Solubility In Water

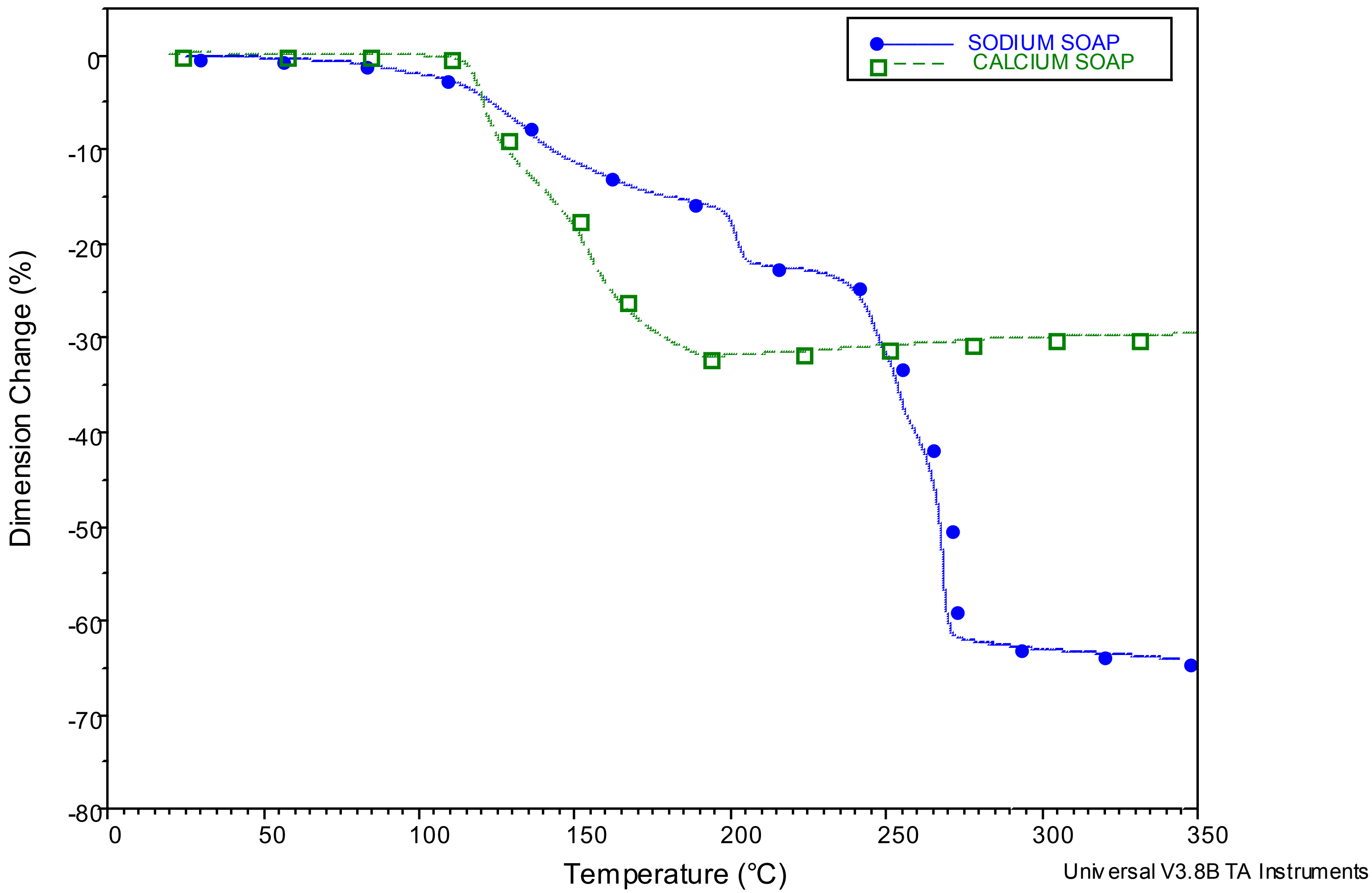
1. SOLUBLE

FATTY ACID + CAUSTIC SODA (LYE) ➔ SODIUM SOAP + H2O

2. INSOLUBLE

FATTY ACID +LIME ➔ CALCIUM SOAP + H20

Dry Soap Solubility Effect On Softening Point



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Dry Soap Classification

Dry Soaps Are Classified By The Amount Of Fatty Acids Present

Lean - Low In Fat Content <50%

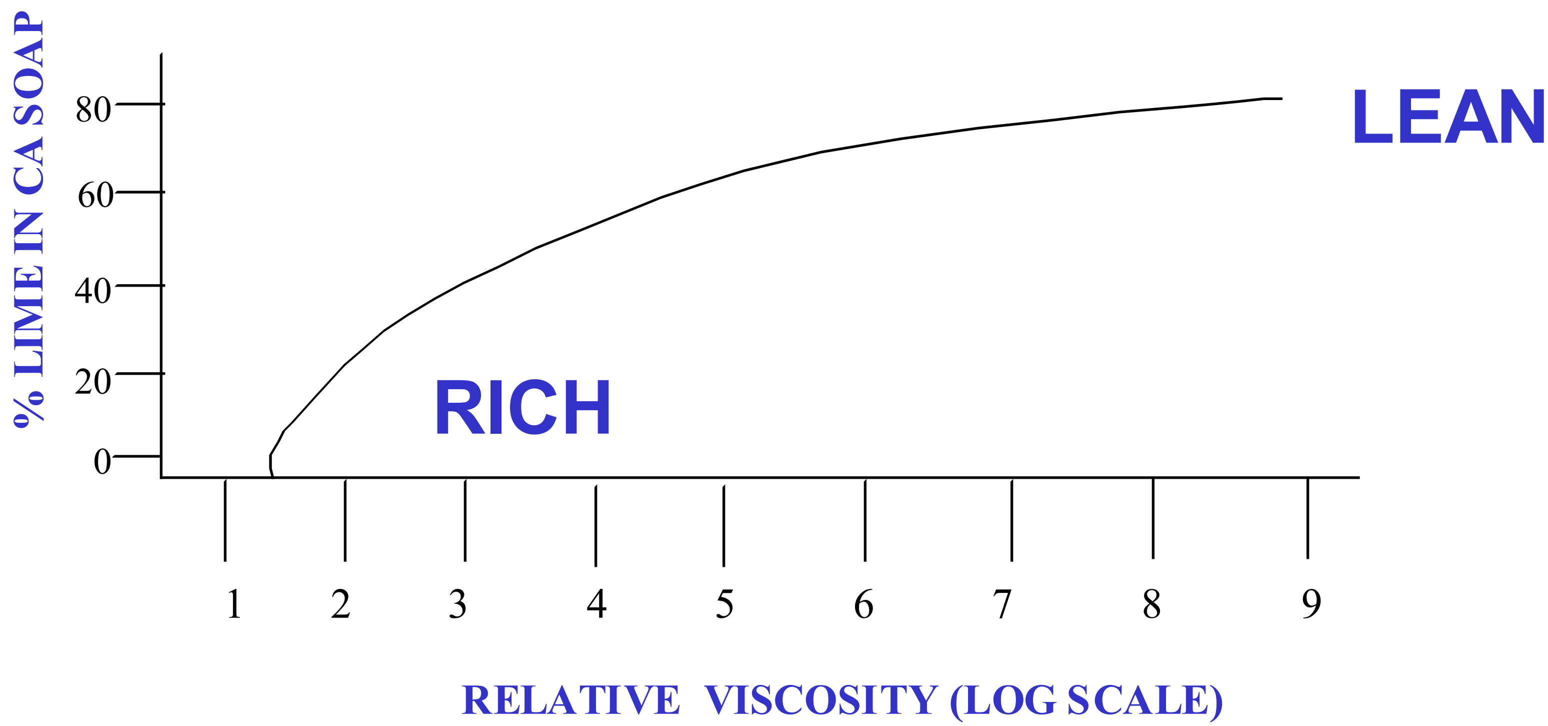
Rich - High In Fat Content >50%

Lean Soap
30% Fatty Acid
70% Additive

Rich Soap
70% Fatty Acid
30% Additive

Dry Soap Classification

Viscosity Modifiers

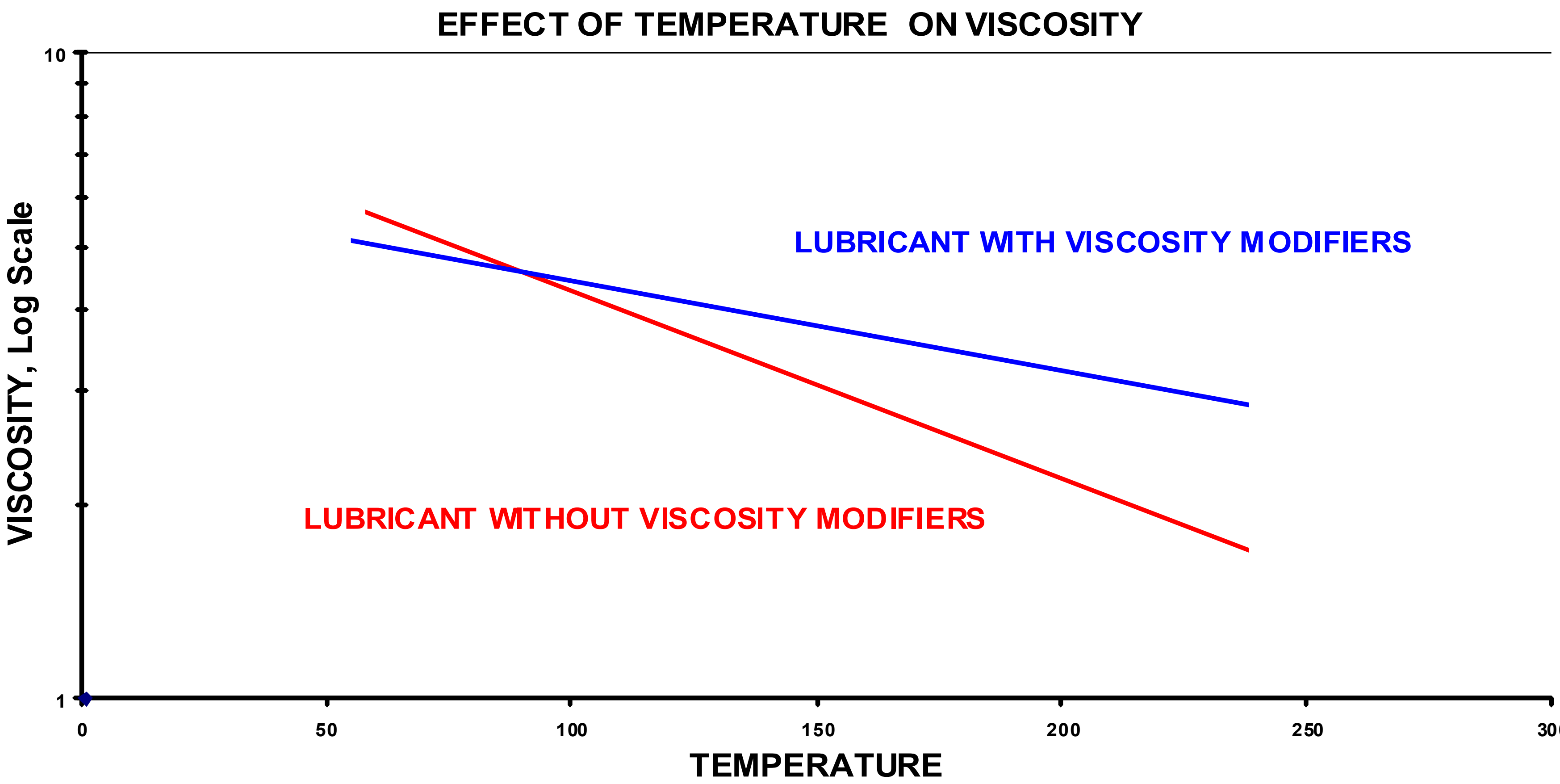


Choice of thickener depends on application and end product use

Ferrous Wire Handbook, Vol 1, Chapter 12, The Wire Association International Inc. 1989

Dry Soap Classification

Viscosity Modifiers



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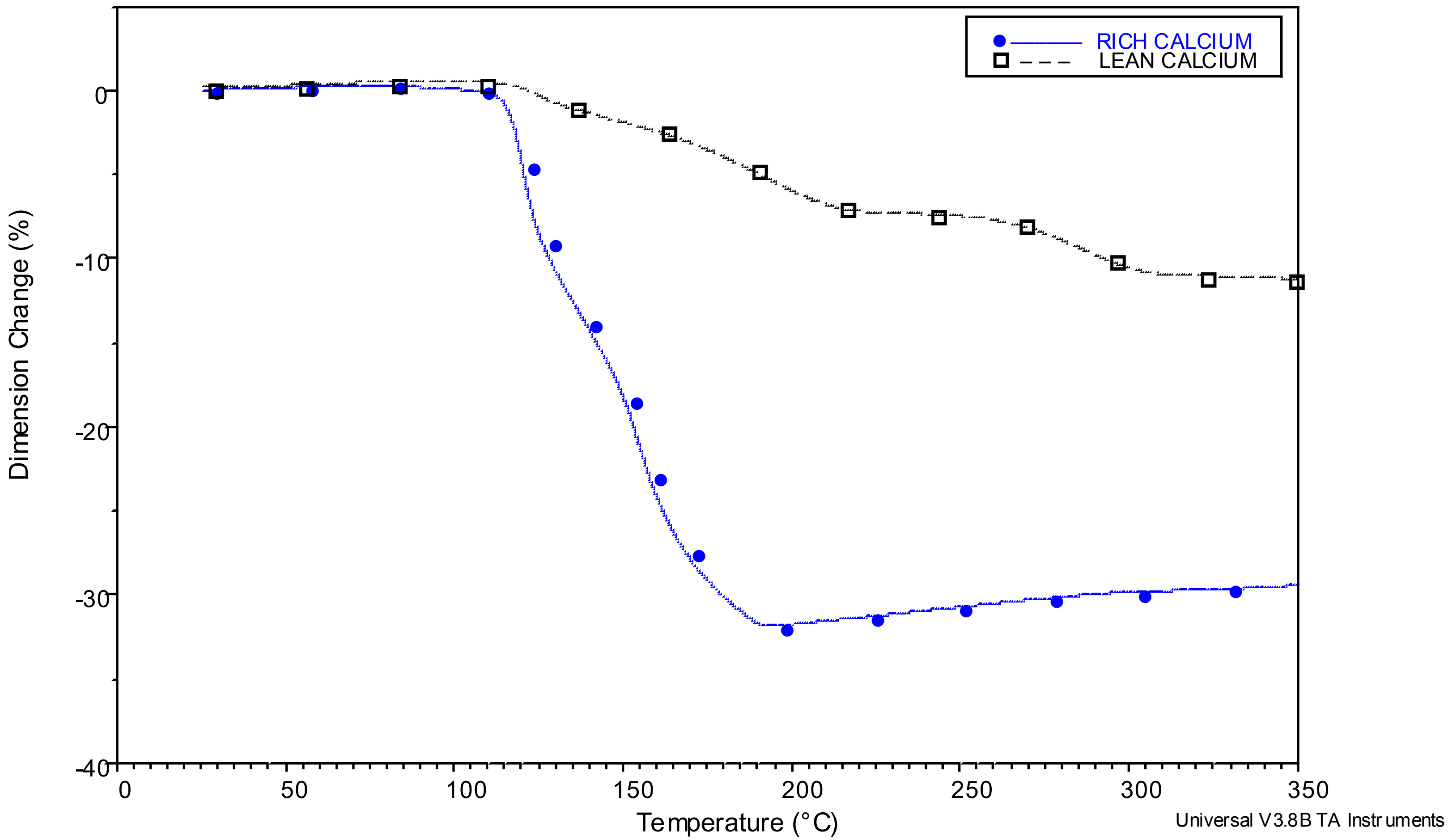
Dry Soap Fat Content Effect On Softening Point



Dry Soap Classification

<u>Dry Soaps Are Classified By The Titer Of The Fatty Acid</u>

- The titer is a measurement related to the melting point of the fatty acid and correlates with the amount of unsaturation and molecular weight distribution

(Saturated)	TITER °C	
• Stearic Acid	52 – 60	HIGH
(Unsaturated)		
• Tallow Fatty Acid	38 – 44	LOW

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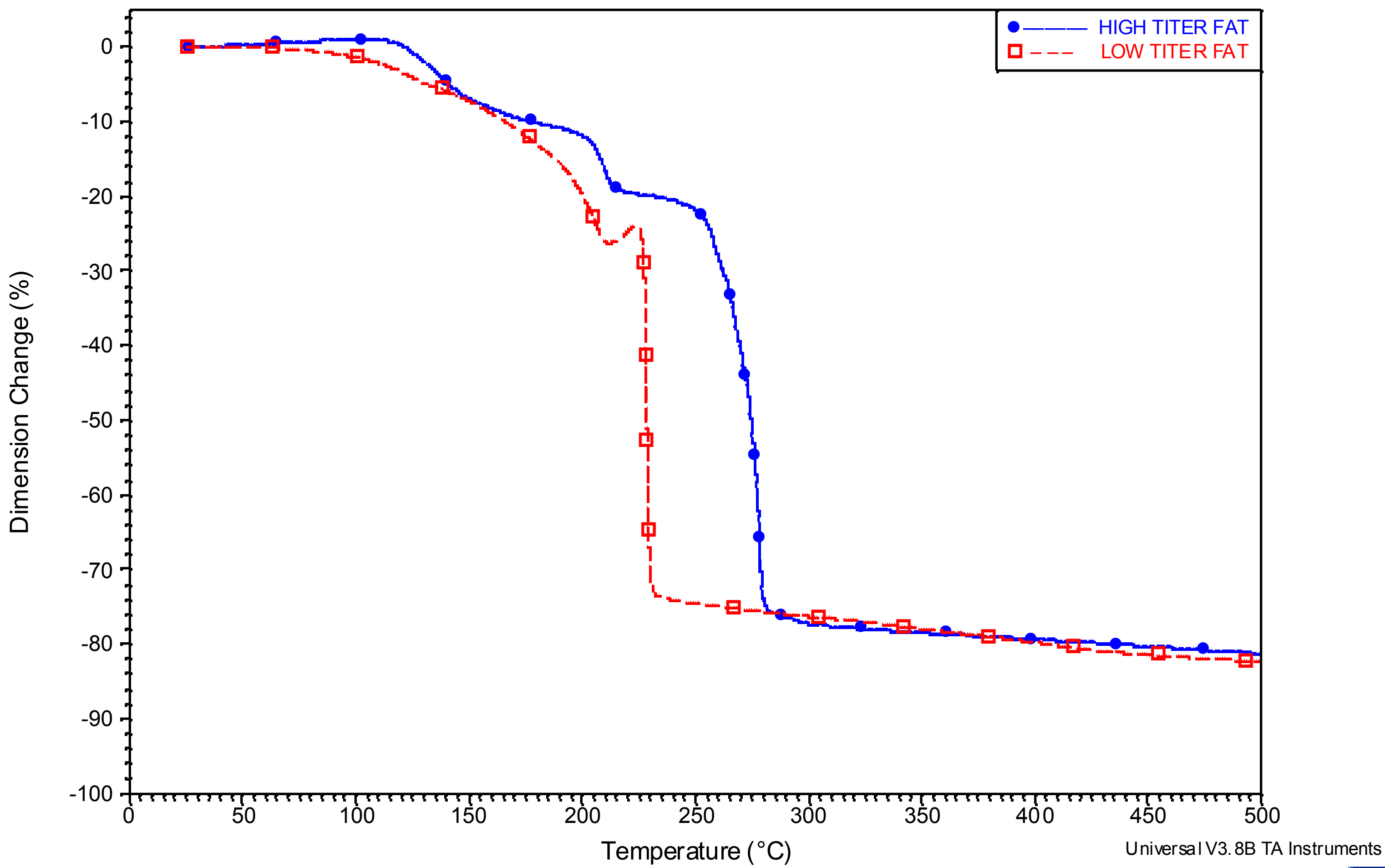
Dry Soap Titer Effect On Softening Point



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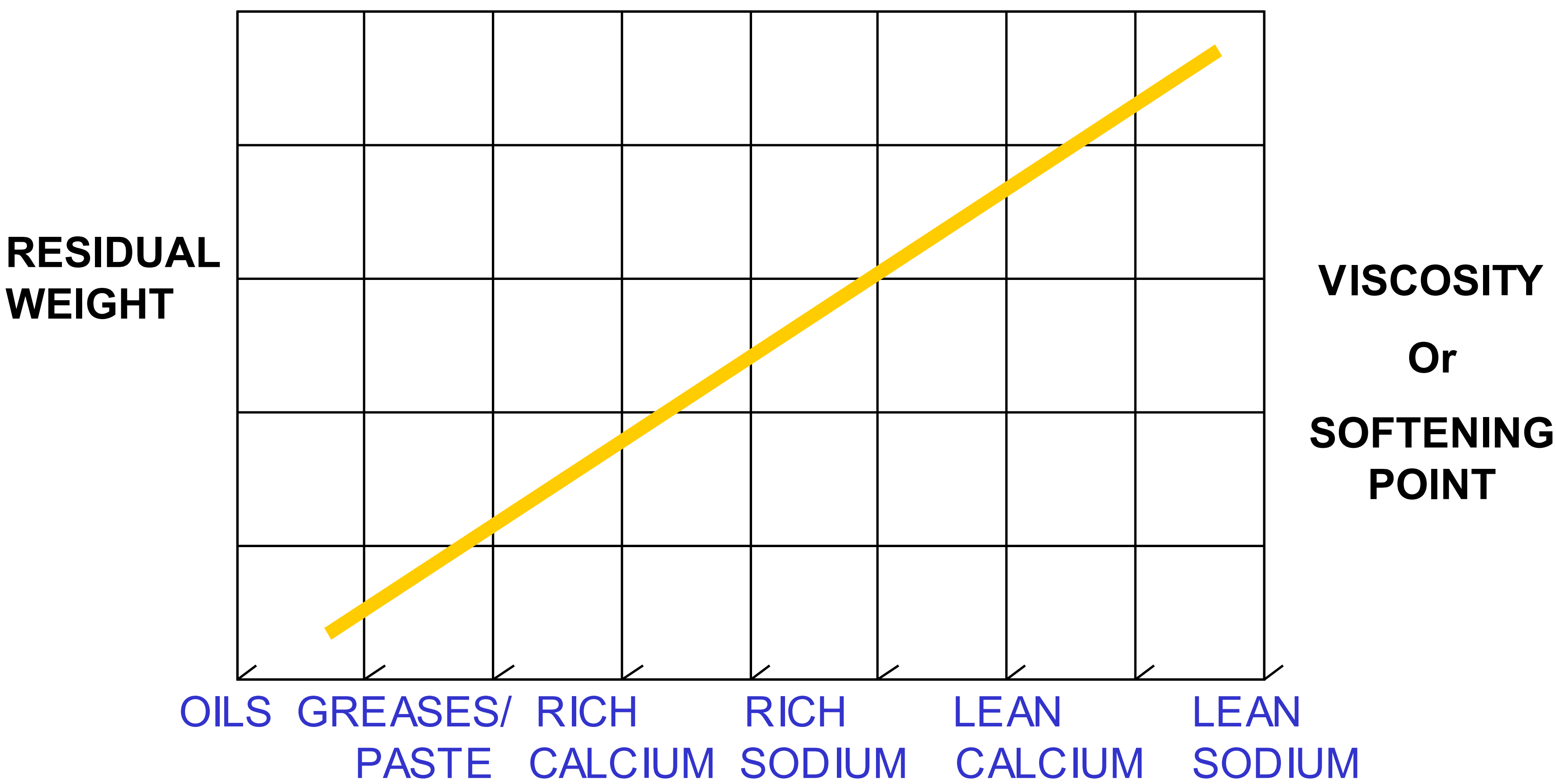
Residual Weight Vs. Lubricant Type



TEMPERATURE = CONSTANT

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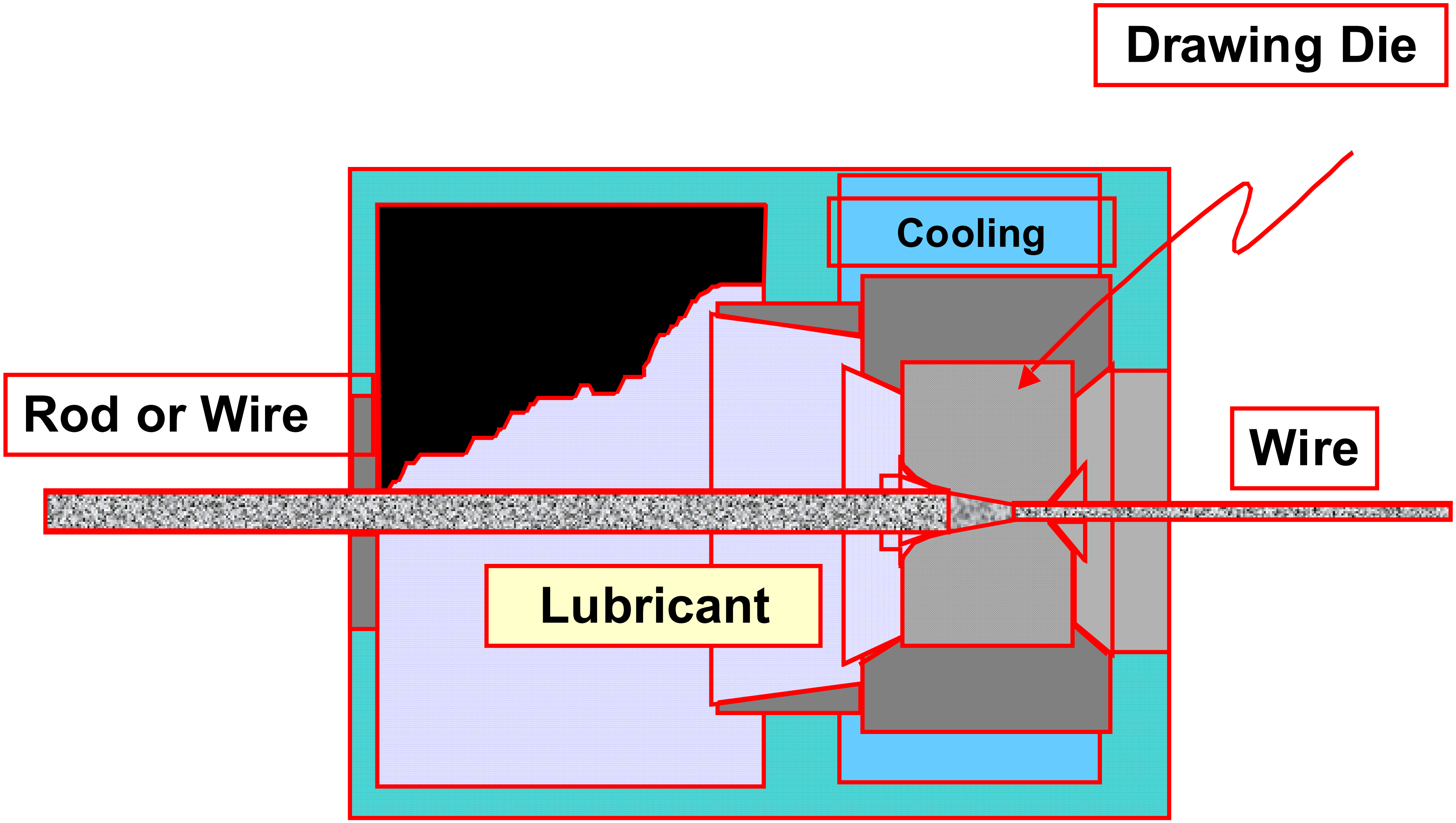
Dry Soap Box



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Factors Affecting Wire Drawing Dry Lubricant Selection

- Composition of the metal to be drawn
- Surface condition of rod and wire
  - Bare metal
  - Coated metal
  - Pre-coat chemistry
- Drawing speed
- Drafting practices
- Die design
- Machine design and constraints
- Down stream use of wire

Effect Of Residual Film On Die Life And Wire Quality

More residual film or better die life	Less residual film or cleaner and brighter surfaces
Apply heavier Precoat residuals	Apply lighter Precoat residual
Use leaner (more filler – less fatty acid) lubricant	Use richer lubricant
Use higher titer soaps (higher melting point FA)	Use low titer soap
Use EP additives	No moly or sulfur to be used
Use straight calcium based lubricants	Use partially soluble or soluble soaps

Lubricant Variables Affecting Residual Film Thickness

VARIABLES	RESIDUAL FILM THICKNESS	
	HIGH ⟶	LOW
% Fat	30	75
Titer of Fatty Acid ºC	60	35
% Thickener	70	25
EP Additives	Present	Absent
Soap Type	Calcium	Sodium
Grind Size	Fine	Coarse

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External Factors Affecting Residual Film Thickness

VARIABLES	RESIDUAL FILM THICKNESS	
	HIGH	→ LOW
Rod Surface	Rough	Smooth
Borax	200 g / l (27 oz / gal)	50 g / l (7 oz / gal).
Lime	12% Triple Dip	2%
Phosphate	21 g / m^2 (2000 mg / $ft^{2)}$	3 g / m^2 (300 mg / $ft^{2)}$
Temp. of Wire	70° C	260º C
Drawing Speed	90 mpm (300 fpm)	900 mpm (3000 fpm)

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External Factors Affecting Residual Film Thickness

VARIABLES		RESIDUAL FILM THICKNESS
		HIGH ⟶ LOW
Die Box (Pressure Dies)		All Boxes Ripper Only No Boxes
Mechanical (Applicator)		All Boxes Ripper Only No Boxes
Dies	Included Angle	8° 10° 12° 14° 16° 18° 20° 22° 24°
	Bearing Length	20% 80%