Concrete Mold Release

January 2021

Concrete

- Concrete is a crystallized conglomerate of aggregate and binder made using a thick water-based paste either to pour on site or made precast structures

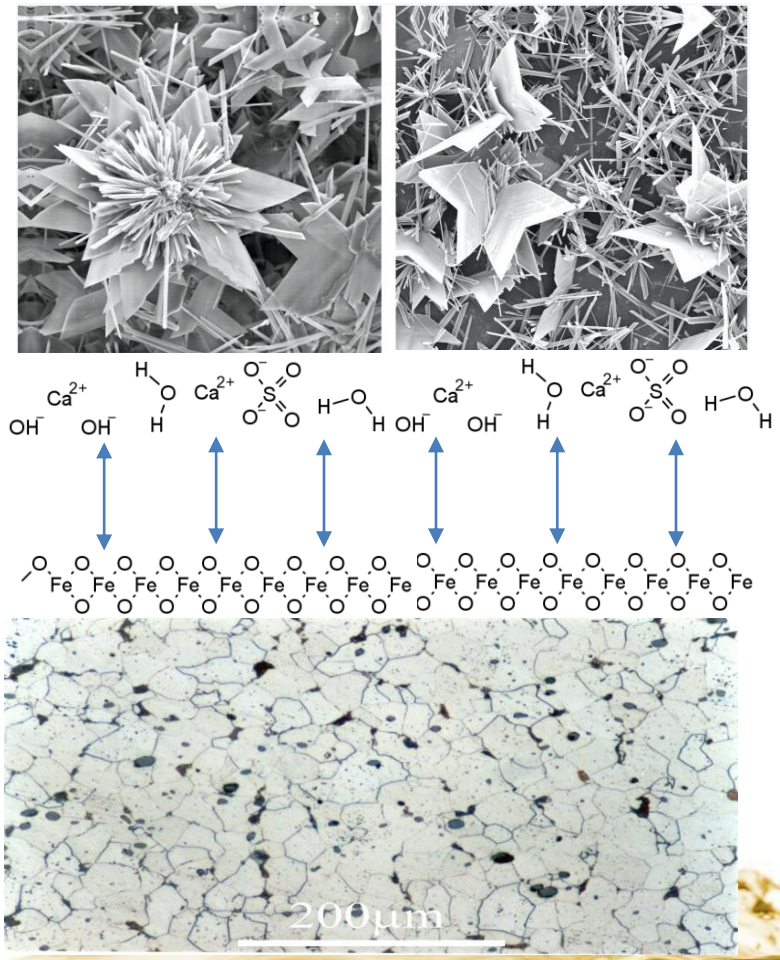
Component	Subcomponents	Vol% Concrete
Portland cement (binder)	Ca3Al – 10% $Ca_4Al_2Fe_2O_{10}$ - 8% Ca_2SiO_5 - 20% Ca_3SiO_4 – 55% $Na_2O + K_2O$ – 2% $CaSO_4$-$2H_2O$ – 5%	~19%
Aggregate	Sand / Limestone / Gravel	~56%
Water	Water	~25%

- Plus any admixtures like accelerators, corrosion inhibitors, polymers

https://www.engr.psu.edu/ce/courses/ce584/concrete/library/construction/curing/composition%20of%20cement.htm
http://matse1.matse.illinois.edu/concrete/prin.html

Surface Interaction

Ca/Al/Fe silicates, sulfates, and hydrates (concrete)



Carbon steel (walls of mold)

https://www.zkg.de/en/artikel/zkg_Superplasticizers_in_the_calcium_sulfate_system_plasticizing_action_and_1592413.html
https://doitpoms.admin.cam.ac.uk/miclib/micrograph_record.php?id=206

Release Agent Need

- Ca/Al/Fe/Si oxides and hydrates in the concrete can form strong ionic and hydrogen bonding with metal oxides on metal or celluloses in wood
  - Adhesion, if only occasional, causes:
    - unwanted defects in the concrete piece
    - corrosion or pitting of the mold (reduced life, increased equip. costs)
    - and increased time to remove and clean the mold (longer cycle time)
- Typically not required in rubber-based molds (low surface energy hydrocarbon material with no polarity or hydrogen bonding) but required for wood or metal forms

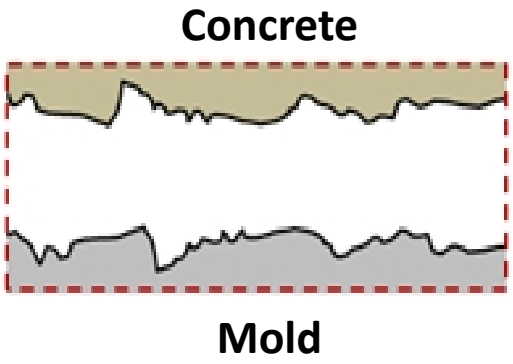
CMR-1001

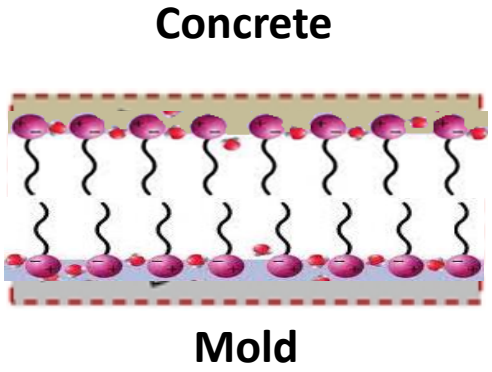
- FUNCTIONAL CMR-1001
  - Concrete mold release additive
    - Reactive type
  - Use 3wt% in most cases
  - Biobased but functions in both veg oil and mineral oils
    - Not designed for emulsions; if interested, use non-ionic emulsifiers

Mechanisms

- Release agent is sprayed / painted / wiped onto the mold to prevent contact and bonding between the concrete and the mold surface

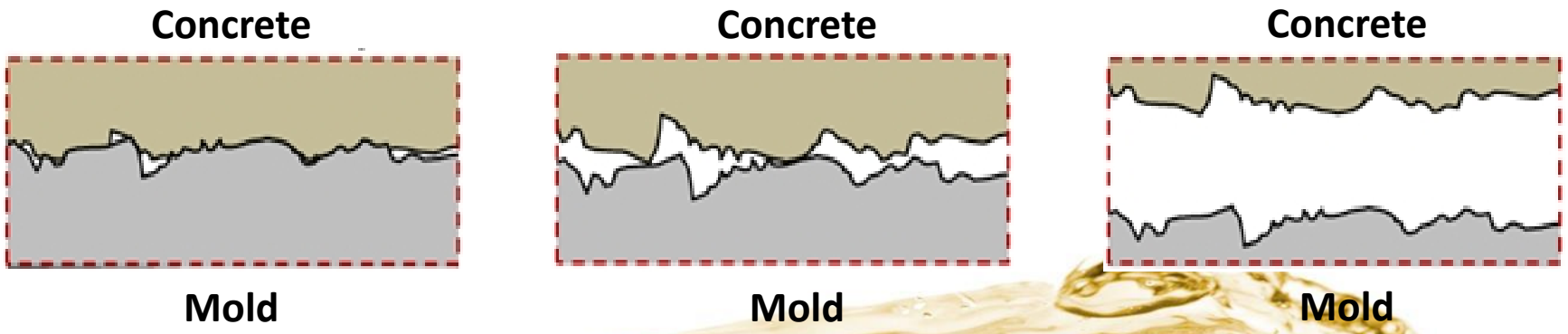
- Barrier vs. Reactive types of release agents





Barrier Mechanism

- Barrier mechanism uses a viscous, low surface tension fluid to coat between two high surface energy materials (concrete and mold)
  - “Film strength”
- Tend to be higher viscosity (ISO 46 paraffinic oil or vegetable oil)
- Lowest cost but tends to form surface defects
- Used for disposable or inert (rubber) molds

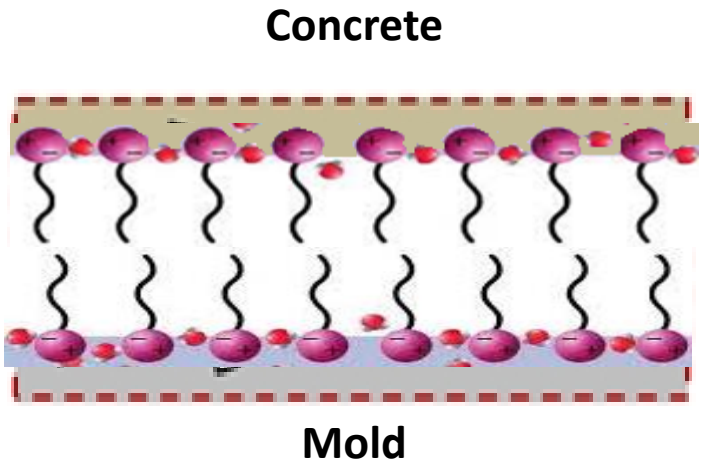


Reactive Mechanism

- Reactive mechanism uses acids or complexing agents to form a passivating soap at the surface of the concrete
  - “Soap”

- Tend to be lower viscosity (ISO 5 – 15)
- Most common now

- **FUNCTIONAL CMR-1001**
- **FUNCTIONAL CMR-1001RO**



Pain Points in Mold Release

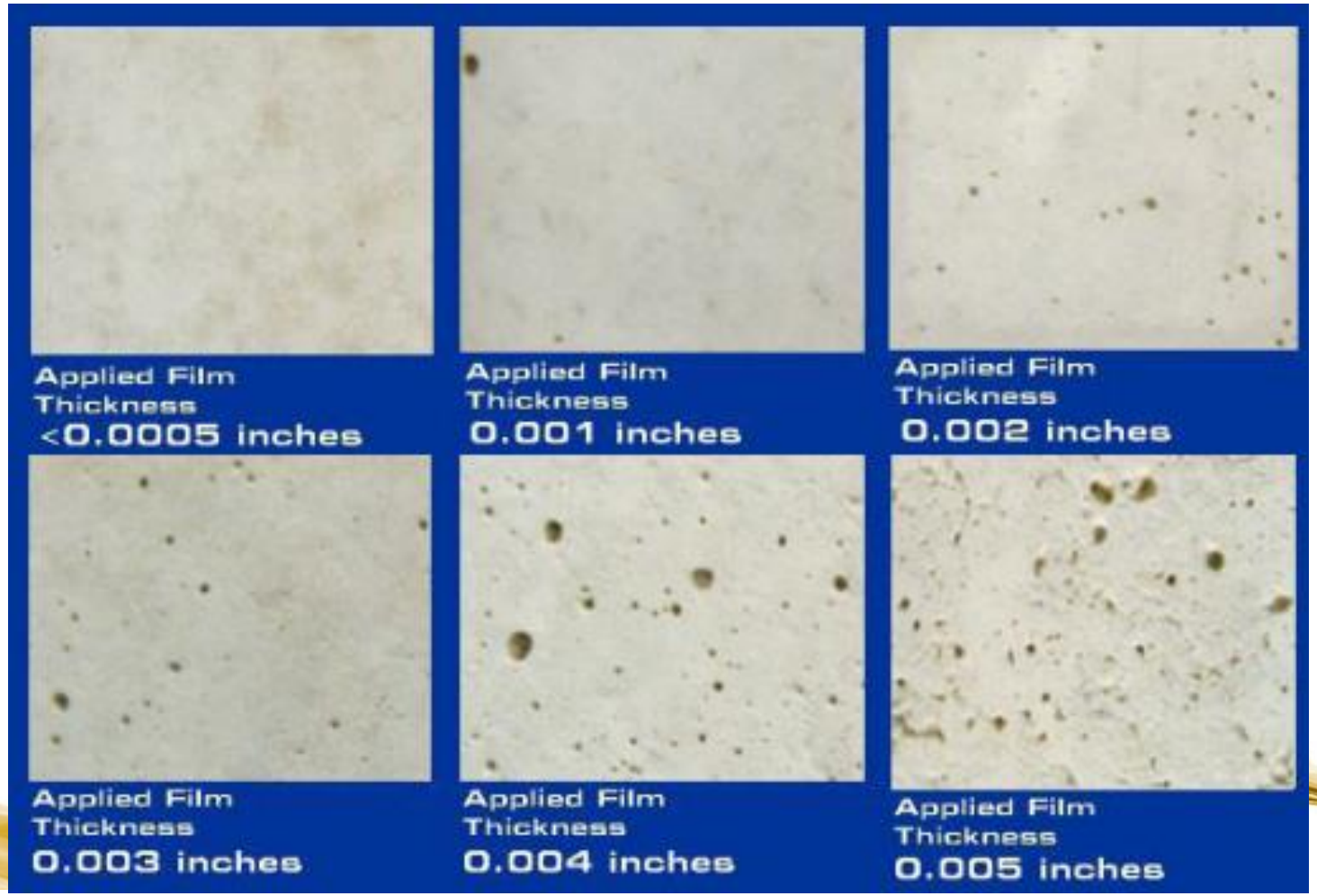
- With respect to…
  - Surface finish
    - Discoloration
    - Surface voids (bug holes)
    - Dusting concrete
  - Mold design
    - Material (metal, rubber, wood, fiberglass)
    - Complexity of shape and draft angles
    - Corrosion of metal components
  - Release agent
    - Pooling of agent
    - Sticking residue to mold
    - Cost
  - Environment
    - Volatility/flammability/inhalation and worker safety
    - Effects of overspray
    - Indoor/outdoor operations

Defects

- Surface voids / bug holes
  - Puddles or a layer of release agent applied too thickly traps air and causes the bubble to cure as a hole on the surface
- Dusting
  - Too much release agent causes the surface of the concrete to cure weakly and be prone to flaking off (forming dust)
  - Can also be due to concrete formulation
- Pinholes
  - Mold surface not cleaned properly between uses
- Oil stains
  - Too much release agent is used and remains on surface; discolors over time with light / heat / air

Viscosity / Film Thickness

- Film thickness determines surface finish
  - Thicker films trap air and create voids during cure
  - **Film Thickness** = **Amount Applied** + **Viscosity** + **Temperature**

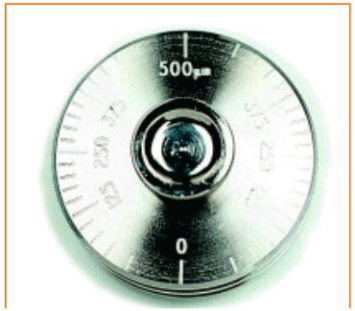


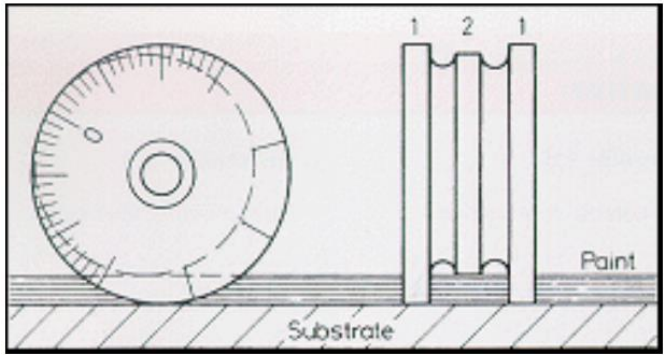
Images from Cresset - CCS GUIDE – (CRESSET CONCRETE STANDARDS)

Measuring Film Thickness

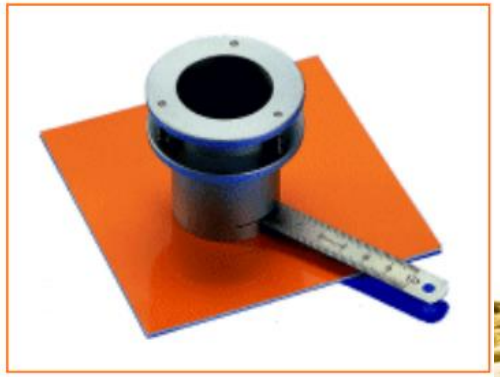
- Wet film wheel from Elcometer, ~$300-400/per
  - 0 – 100 micron w/ 5 micron resolution

Elcometer 3230 Wet Film Wheels





- Optical - Pfund Thickness Gauge
  - 2 – 360 micron

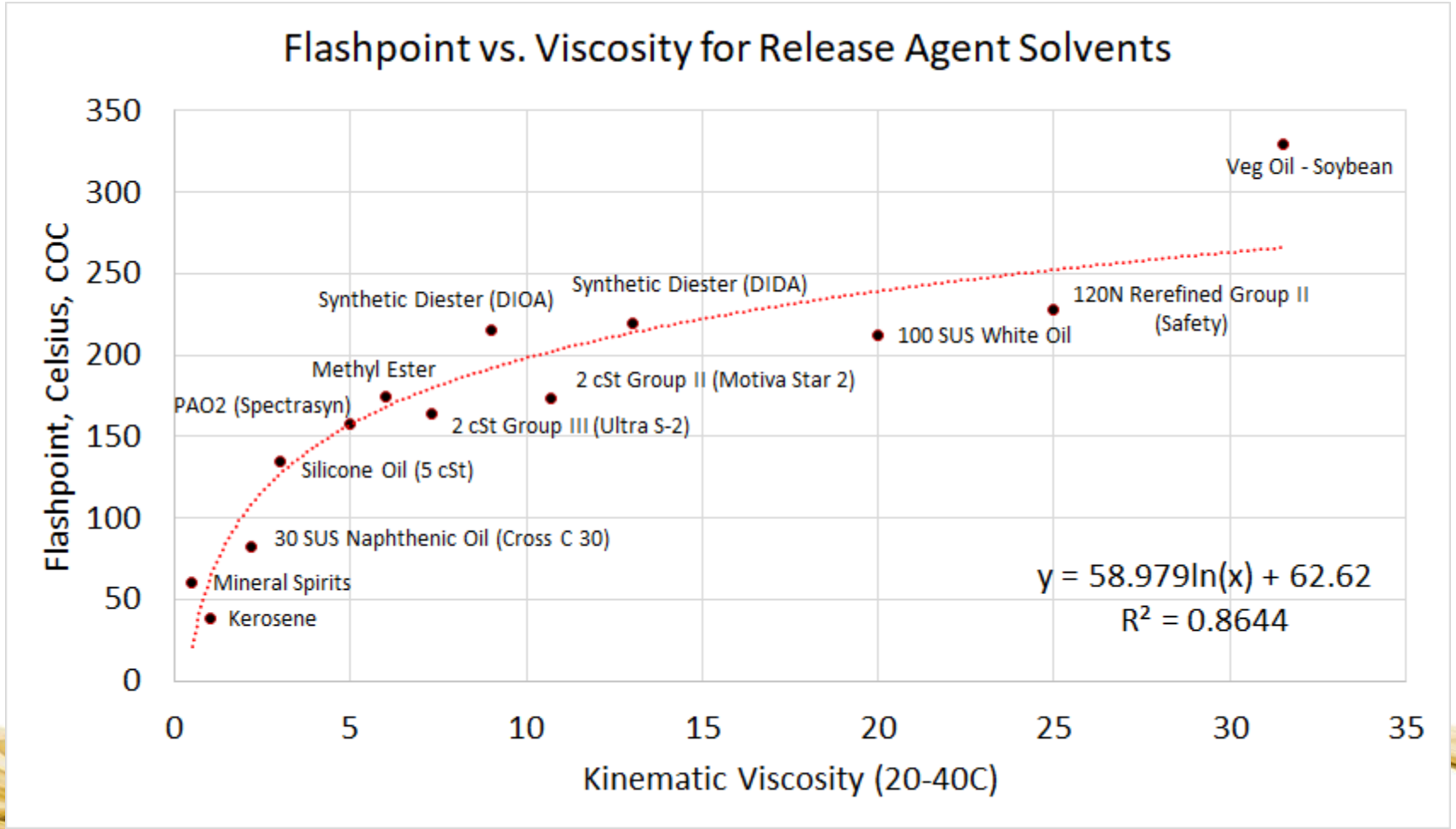


Elcometer 3233 Pfund Thickness Gauge

https://www.elcometerusa.com/Elcometer-3230-Wet-Film-Wheels-Range-0-100m-Metric-K0003230M003.html?gclid=Cj0KCQiAmL-ABhDFARIsAKywVadyuGUYTr0vlF0GKE-tWY5sO6Qdg4TZIsKVLTRCWBAJbR0-iZKX6B8aAk6eEALw_wcB

Volatility vs. Viscosity

- Volatility (flashpoint) closely follows viscosity
  - Esters and highly refined alkanes (paraffins) increase flash
  - Aromatics and cycloalkanes (naphthenes) reduce flash



Release Agent Segments

- 1 – Veg/ester emulsion; no aromatics, no hazards or labeling
- 2 – Straight veg/ester oil; no hazards or labeling
- 3 – Veg/ester + petroleum oil emulsion; no labeling

- 4 – Petroleum oil w/ <0.03% aromatics
  - Add H304: May be fatal if swallowed and enters airways

- 5 – Petroleum oil w/ <2% aromatics, 60-100C flash point
  - Seg 4 hazards + EUH066: Repeated exposure may cause skin dryness/cracking.

- 6 – Petroleum oil w/ <2% aromatics, 23-60C flash point
  - Seg 5 hazards + H226: Flammable liquid and vapour
    - And H335: May cause respiratory irritation

- 7 – Petroleum oil w/ >2% aromatics, 23-60C flash point
  - Seg 6 hazards + H411: Toxic to aquatic life with long-lasting effects

Base Fluid by Segment

- Based on composition, viscosity/flashpoint, and % aromatics

Segment	Petroleum	Biobased
1 – ester + water		Vegetable oil, methyl ester, synthetic ester, water, emulsifier
2 – straight ester		Vegetable oil, methyl ester, synthetic ester
3 – ester + petroleum	White oil (< 100 SUS), Group III (2-4 cSt), PAO2	
4 – petroleum, very low aromatics	White oil (< 100 SUS), Group III (2-4 cSt), PAO2	
5 – medium flash, low aromatics	Group II paraffinic; process or naphthenic oils (≤ 35 SUS); T3 mineral spirits	
6 – low flash, low aromatics	Isoparaffins; T1/T2 mineral spirits, odorless	
7 – low flash, high aromatics	Kerosene	

Safe Solvent Options

- Low viscosity, high safety fluids to build CMR fluids with:

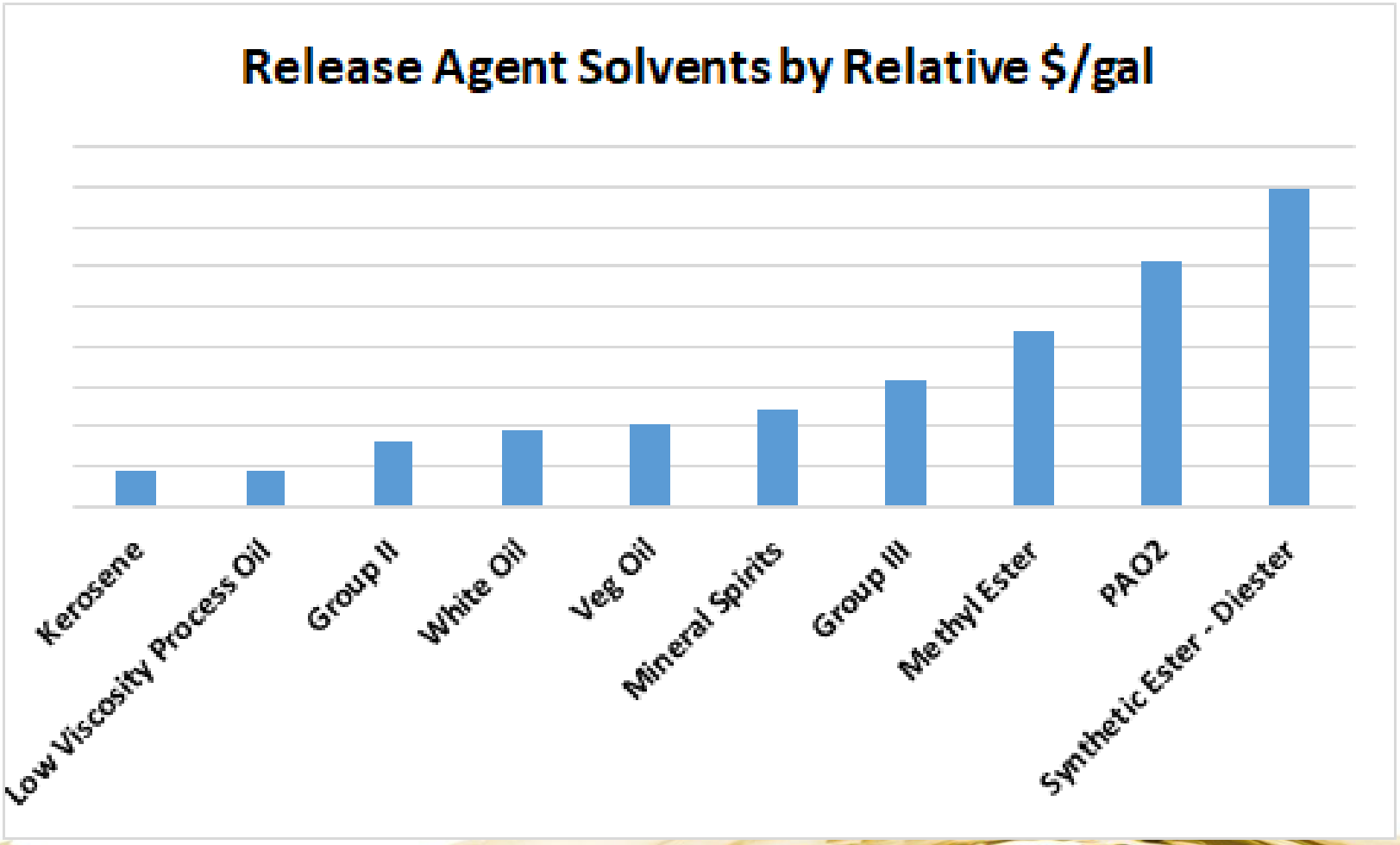
Formula by wt%	Flashpoint, C	KV 20	KV 40	KV 100	% Aromatics	Asp Tox 1 Haz?
Naphthenic 35 SUS	94	3.7	2.8	1.2	0 – 20	Y
Methyl Ester	130	10.2	4.6	1.7	0	N
PAO 2	158	12.8	6.7	2.0	0	Y
Dioctyl Adipate	215	17.9	9.4	2.8	0	N
Paraffinic/WO 65 SUS	212	18.8	9.3	2.5	0.01 – 10	Y
Paraffinic/WO 120 SUS	228	61.1	24.8	4.8	0.01 – 10	N
Vegetable Oil	330	67.3	33.0	8.1	0	N

- Petroleum oils and PAO with viscosity @ 40C of <20.5 cSt are rated with Aspiration Toxicity 1 hazard if present at ≥10wt% of the formula

- Use “naphthenic oils” rather than high aromatic “process oils”
  - Compare brands: Cross Corsol 35 (14% aromatic C) vs. Nynas NS 3 (6% aromatic C) vs. Calsol P904 (2% aromatic C)

Relative Pricing

- Silicone oils at



Silicone oils at 4x lb/gal vs. synthetic ester diester

Historic kerosene pricing

FUNCTIONAL CMR

- Concrete mold release formulating can be as complex as you want it to be

https://www.archdaily.com/900759/a-history-of-concrete-molds-from-thomas-edisons-failed-cement-company-to-habitat-67

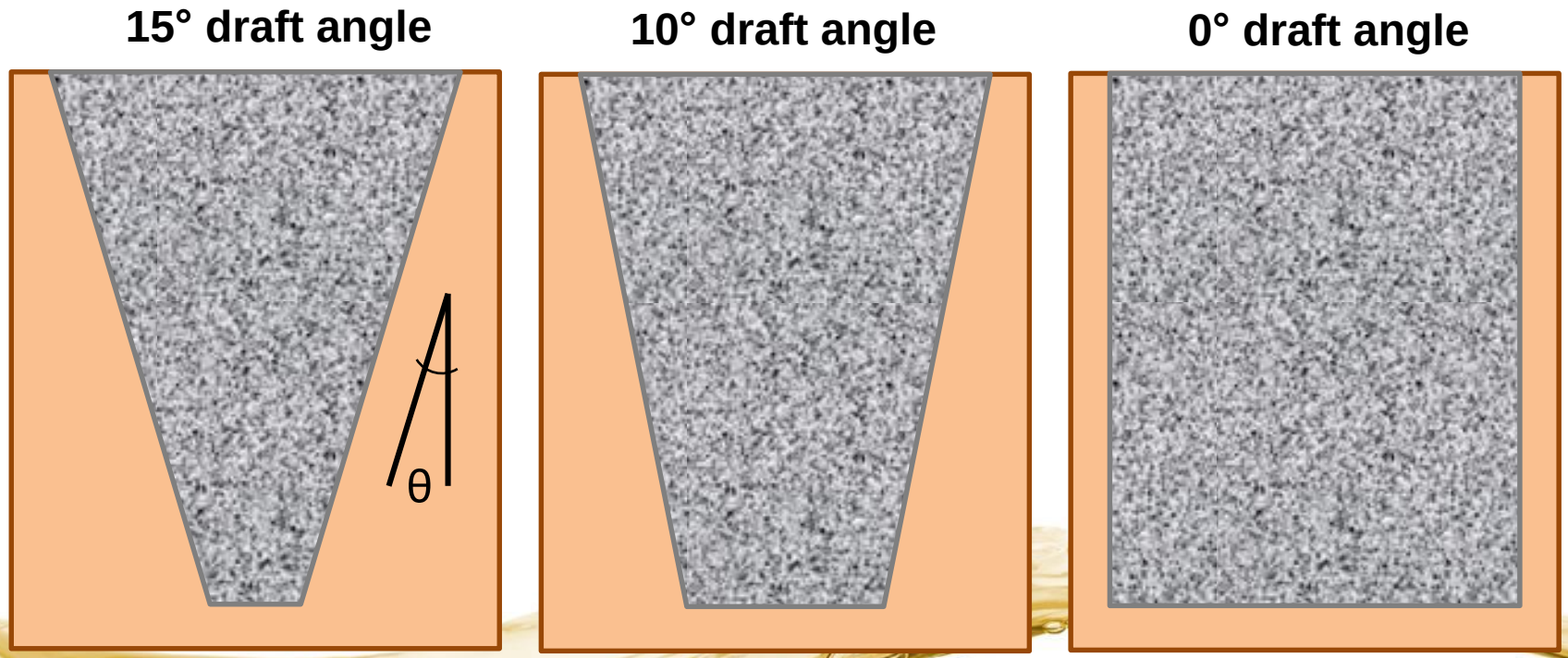
Example CMR-1001 Formulas

Formula by wt%	All-Purpose	Severe Angle	Winterized	Complex Geometry
Base Fluid	97%	94%	96%	93%
FUNCTIONAL CMR-1001	3%	6%	3%	3%
FUNCTIONAL PD-590			1%	
FUNCTIONAL V-584				4%
FUNCTIONAL DF-500				
Merits	-Low color, low VOC, non-toxic and biodegradable formula	-Extra strength release aid for molds with severe draft angles or length	-Improved cold temperature fluidity for outdoor operations -Improved cold storage capability	-Anti-drip / anti-sag formulation for molds with complex shapes and vertical or upside-down surfaces -Reduced pooling and bug-holes/voids
wt% Biobased Content	>99%	>99%	>99%	>99%
Pour Point (ASTM D97)	-12C / 10F (if using soy) -24C / -11F (if using canola)	-12C / 10F (if using soy) -24C / -11F (if using canola)	-27C / -17F (if using soy) -36C / -33F (if using canola)	-12C / 10F (if using soy) -24C / -11F (if using canola)

Draft Angle

- Angle to the taper between the mold walls
  - 5-15° common, use 3% CMR-1001

- Lower angle = more surface contact and difficulty to remove (more CMR)
  - < 5° considered “severe”, use 6% CMR-1001



Cresset Petroleum Formulas

- Cresset **CRETE-LEASE® 880-THE ORIGINAL**
  - Mineral Spirits 40-50%, Naphthenic Oil 45-50%, Fatty Acid Salt 4-5%
  - GHS Hazards – Flammable 3, Aspiration 1, Eye 2B, Skin 2, STOT 3
  - 80C flashpoint, 440 g/L VOC, 6 cSt @ 20C, -26C freezing point

- Cresset **CRETE-LEASE 880-VOC-XTRA Release Agent**
  - Hydrotreated light distillates 20-25%, Naphthenic Oil 75-80%, Fatty Acid Salt 2-5%
  - GHS Hazards – Aspiration 1, Skin 2, STOT 3
  - 220C flashpoint, 240 g/L VOC, 15 cSt @ 20C, -26C freezing point

Heavier Petro. Formulas

- Cenex **Concrete Form Oil**
  - Hydrotreated light distillates 60-100%; reactive add. present, unlisted
  - GHS Hazards – Aspiration 1
  - 149C flashpoint, <450 g/L VOC, 11.5 cSt @ 40C, -40C freezing point

- Cresset **CRETE-LEASE 880-VOC-XTRA Release Agent**
  - Hydrotreated

Cresset Biobased Formulas

- Cresset **CRETE-LEASE® BIO-TRU®-XTRA RELEASE AGENT WITH POLY-RELEASE®**
  - 80C flashpoint, 440 g/L VOC, 6 cSt @ 20C, -26C freezing point

- Cresset **CRETE-LEASE® BIO-TRU®-ALL-XTRA RELEASE AGENT WITH POLY-RELEASE**
  - USDA Biopreferred
  - 220C flashpoint, 240 g/L VOC, 15 cSt @ 20C, -26C freezing point

Biobased Mold Release

- Renewable Lubricants's **Bio-Concrete Mold Release Fluid (Plus Corrosion Inhibitor)**
  - No composition info on SDS
  - 220C flashpoint, no VOC, 5 cSt @ 40C, -10C freezing point; 7.26 lb/gal

- US Spec's **Ezkote Green**
  - No composition info on SDS
  - 130C flashpoint, no VOC, 60 SUS viscosity, -23C freezing point, yr shelflife

- Nox-Crete's **Bio-Nox VS**
  - 15-40% petroleum distillates; Aspiration Toxicity 1
  - 63C flashpoint; <250 g/L VOC; -7C freezing point; 7.3 lb/gal

- Harmonious Enterprise's **Green Release**
  - 40% canola oil + "esters and fatty acid"
  - 160C flashpoint; <2 g/L VOC; -10C freezing point; 7.5 lb/gal

CMR-1001RO

- FUNCTIONAL CMR-1001RO
  - Same treat rates as CMR-1001
  - Improved rust and oxidation performance
    - Low color change for high temperature curing
    - Prevent rust and rust stains if metal involved in the mold

Metal Form Corrosion

- Reactive-type release agents or breakdown of ester-based barrier products can attack metals

- Added time to clean the concrete post-production and refinish/replace the mold

CMR-1001RO Starting Formulas

Formula by wt%	Rust-Proof	High Performance
Base Fluid	97%	94.9%
FUNCTIONAL CMR-1001RO	3%	3%
FUNCTIONAL PD-590		
FUNCTIONAL V-584		2%
FUNCTIONAL DF-500		0.1%
Merits	-Protection against rust formation and rust stains in reinforced concrete or molds	-Best surface finish due to anti-sag/drip and silicone-free anti-foam formulation -Excellent color stability -Rust resistant to prevent staining
wt% Biobased Content	>99%	>99%
Pour Point (ASTM D97)	-12C / 10F (if using soy) -24C / -11F (if using canola)	-12C / 10F (if using soy) -24C / -11F (if using canola)

Biodegradability

- ASTM D7373 – calculated biodegradability of petroleum + ester blends
  - Biobased Esters – 100%
    - Soybean Oil, Canola Oil, Methyl Esters
  - Renewable Synthetic Esters – 80%
    - Dioctyl adipate, diisodecyl adipate, TMP trioleate
  - PAO 2 – 80%
  - Petroleum Oils – 30% (of non-aromatic content)
    - Use Gr II/III, white oil, isoparaffin, or highly refined naphthenic oil; goal is low or no aromatics

- **Blends that meet 60% 28-day biodegradation by ASTM D7373 math:**
  - ≥60% veg oil or methyl ester + ≤40% petroleum oil
  - ≥80% PAO2 + ≤ 20% petroleum oil
  - ≥80% adipate + ≤ 20% petroleum oil

US EPA and USDA

- US EPA
  - VOC standard is <450 g/L
    - ASTM E1868, test at Engineered Lubricants in St. Louis Missouri
  - US EPA Safer Choice Ingredient List (SCIL) – https://www.epa.gov/saferchoice/safer-ingredients#searchList
- USDA BioPreferred program
  - Requires 87% of all carbon to be biobased for “Concrete and Asphalt Release Fluids” category
  - Uses radiometric carbon isotope testing

Other Technologies

- Kerosene
- High viscosity oils
- Castor oil
- Water-based emulsions
- Fluorosurfactants
- Silicone oils and emulsions
- Polyethylene/carnuba wax or petrolatum dispersions

- Many other technologies will affect paintability or post-treatment of the concrete surface (silicones, waxes, fluoro-)

Release Agent Producers

- CO: US Spec
- CT: Miller-Stephenson
- FL: MAPEI, Prestress Supply Inc.
- GA: US Formliner
- IL: Fister Inc.
- MI: Strong Products LLC; ChemTrend / Freudenberg; Access Technologies
- NE: **Nox-Crete Products**; Spray-Tech Inc.
- NJ: Sika Corporation
- NY: Scott System
- OH: **Cresset Chemical Co**; **Dayton Superior**; Master Builders Solutions; **Euclid Chemical Company**; **Hill and Griffith (Grifcote)**
- PA: Architectural Polymers, Inc.; APL Supply; Smooth-On Inc.; McLube
- MA: GCP Applied Technologies
- SC: Don Construction Products Inc.
- TX: CHRYSO Inc

- UK: **Ecoratio**

Big incumbents in **bold**; incumbents with excellent online resources are **underlined**

Organizations

- National Precast Concrete Association
  - Precast.org
  - Annual Show
  - https://precast.org/theprecastshow/sponsors/

- Precast/Prestressed Concrete Institute
  - https://www.pci.org/PCI/Directories/SupplierAssociateMember.aspx
  - Search “Release Agents”

Guides to Release Agents

- Choosing and Using a Form Release Agent (Concrete Construction, 1996)
- Form Release Agents (PCI paper, 1975)
- Release Agents – What are they? How do they work? (Cresset paper, 2017)
- Proper Application of Release Agents (NPCA paper, 2015)

Summary

- Concrete release agents
  - Two types
    - Barrier agents – “film strength” of higher viscosity oil (ISO 32-46)
      - Could use FUNCTIONAL VMs or tackifiers to help
    - Reactive agents – reactive, forms a passivating soap between concrete and mold; low viscosity and volatile (ISO ≤15)
      - CMR-1001
      - CMR-1001RO for improved oxidation and corrosion stability
- Formulating is a balance of viscosity vs. volatility vs. safety vs. cost