HANDMADE EMULSION

For Motion Picture Film

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Preface

Below is the proposed agenda for the workshop *Handmade Emulsion for Motion Picture Film*. The workshop is split into two days, the first of which focuses on the theory and practical aspects of photographic emulsion chemistry and the second of which explores working methods and practical experimentation with photographic emulsions.

Prior to the Workshop

Any work needing to be complete prior to the workshop will need to be facilitated several days in advance of the workshop date. This includes....

<u>One Week Prior to the Workshop</u>

- Preparation of 400 feet of 16mm, single perforated cellulose triacetate for coating
- Execution of any necessary experiments & test
    - Emulsification test
    - Coating test

<u>Two Days Prior to the Workshop</u>

- Inspection of all necessary facilities
- Inspection of all necessary equipment
- Preparation of materials & equipment for the workshop

Day I [8.5 hours]

This day will be dedicated to discussions and demonstrations concerning the theory and technique of emulsion chemistry. Practical exercises will be limited, but not excluded...

<u>Introduction [0.5 Hours]</u>

1. General Introductions
2. What is a handmade emulsion
3. Why handmake emulsion
4. Goals of this workshop

<u>The Silver Gelatin Emulsion [1 Hour]</u>

1. Conventional History of Silver Gelatin Photography
    a. Nicéphore Niépce (France)
        i. *View from the window at Le Gras* (1826)
        ii. Process
            1. Hardening of bitumen of Judea (asphalt) to daylight
            2. Long exposure time (i.e. printing out process)
            3. Removal of unhardened bitumen with oil of lavender & white petrolum
        iii. Impossibility of reproduction
    b. Louis Daguerre (France)
        i. The Daguerreotype Process (1839-1860)
            1. Sensitization of a silver plate by Iodine, Bromide or Chloride fumes
            2. Relatively short exposure time...
            3. Amplification by Mercury Vapors (i.e. developing out process)
        ii. Free use
        iii. Lack of reproducibility
    c. William Henry Fox Talbot (UK)

i. The Calotype Process (1841-1851)
    1. Dual Coating of silver nitrate and Potassium Iodide on paper
    2. Recoating of
ii. John Herschel - Hypo
iii. Patent control
iv. Reproducible
v. Low Sharpness

d. Frederick Scott Archer
i. The Collodion Process (1851 - 1884)
    1. Collodion enriched with bromide, chloride or iodide coated to glass
    2. While still wet, the plate is submerged in a silver nitrate solution
    3. While still wet, the plate is exposed and developed, typically in a pyrogallic acid
ii. Difficulty of process
    1. Loss of sensitivity to plate drying

e. Eastman Kodak - Dry Plate (1884-Present), Celluloid

2. Film Anatomy
a. Base
i. Cellulose Nitrate (1888-1952)
    1. Flammable
ii. Cellulose Diacetate (1909-1948)
iii. Cellulose Triacetate (1948-present)
    1. Non-flammable
    2. Low stability
        a. Decomposes to acetic acid (i.e. vinegar syndrome)
    3. High solubility
        a. Acetone
iv. Polyethylene Terephthalate (1948-present)
    1. Non-flammable
    2. High stability
    3. High durability
    4. Low solubility
        a. Ultrasonic splicing

b. Substratum Layer
i. Gelatin

c. Emulsion
i. Silver Halide (AgHal)
    1. Architecture
        a. The cubic lattice
            i. Silver cations (+)
                1. Ionic radius: 1.26 Å (Ångström)
            ii. Halogen anions (-)
                1. Bromide anions
                    a. Ionic radius: 1.81 Å
                    b. Halide solubility, in water: 2×10^{-8} g. moles/L
                    c. Halide color: pale yellow
                2. Chloride anions
                    a. Ionic radius: 1.96 Å
                    b. Halide solubility, in water: 1.33×10^{-5} g. moles/L
                    c. Halide color: white

3. Iodide anions
    a. Ionic radius: 2.20 Å
    b. Halide solubility, in water: 7.12×10^{-7} g. moles/L
    c. Halide color: pale yellow (deeper hue than bromide)

b. Grain structure
    i. Cubic grains
        1. 100 Faces
        2. 111 Faces
    ii. Tabular grains

ii. Gelatin
1. Function and important characteristics
    a. Suspension of AgHal grains
    b. Reversible gelling properties
    c. Swelling of gelatin in aqueous solutions
    d. Controls the growth of the AgHal
2. Manufacturing
    a. Animal bones / hide →
    b. Inorganic material removed (i.e. calcium phosphate) leaving ossein →
    c. Through liming, the collagen is broken down into amino-acid chains (gelatin) →
    d. Gelatin is extracted from the limed ossein
3. Chemical Properties
    a. Amino-acid backbone
        i. Adsorption by the AgHal
    b. Crosslinking groups
        i. Carboxyl groups with inorganic salts (chromium salts)
        ii. Free amino groups with organic bifunctional reagents (formaldehyde)
    c. Sulphur sensitizers
        i. Active Gelatin (1888-1940)
            1. Degradation of cysteine amino acid
                a. 10-200 ppm of thiosulphate
        ii. Inert Gelatin (1940-present)
            1. Sensitizers
                a. Sodium Thiosulfate [$Na_2S_2O_3$]
                b. Sodium Thiocyanate [NaSCN]
    d. Bromine acceptors
    e. Restrainers
4. Substitutions
    a. ""Such a remarkable combination of useful characteristics seems almost more than coincidence, and one feels that the Almighty must have created the cow with photography in mind. Perhaps the only improvement which one could suggest would be the inclusion of silver halide in the cow."
    - Dr. D.C. Baines, The Science of Photography

iii. Dye Sensitizers
iv. Silver Grain
v. Dye Couplers
vi. Dye Clouds

d. Supplemental layers
    i. Anti-halation layer
    ii. Supercoat

iii. Back coating
iv. Lubricants

Review of Materials [0.33 Hours]

1. Silver halide chemistry
    a. Silver nitrate [$AgNO_3$]
    b. Halogen salts
        i. Potassium Bromide [KBr]
        ii. Potassium Iodide [KI]
        iii. Sodium Chloride [NaCl]
2. Gelatin
3. Finals
    a. Hardeners
        i. Chrome alum [$KCr(SO_4)_2$]
    b. Surfactants
        i. Wetting agents
        ii. Ethyl alcohol
        iii. Distilled water
4. Misc.
    a. Distilled water
    b. Ice

Review of Equipment [0.33 Hours]

1. Safety Equipment
    a. Gloves
    b. Apron
    c. Goggles / Safety Glasses
    d. Respirator
2. Emulsion Making
    a. Essential Equipment
        i. Thermometers
            1. Partial Immersion v. Total immersion
            2. Alcohol v. Mercury
        ii. Hot Plate
        iii. Scale (0.1 gram resolution)
        iv. Safelight
        v. Non metallic (or rust-free, stainless steel) heating vessel
            1. Honeywell processing tanks
    b. Intermediary Equipment
        i. Mag-Stirrer
        ii. Teflon magnets
        iii. Syringes, 100.0 Milliliters or greater
        iv. Glassware
            1. Glass stirring rods
            2. Beakers, 1.0 Liter - 100.0 Milliliters
            3. Graduated cylinders, 1.0 Liter - 25.0 Milliliters
            4. Buchner funnel
        v. Noodle press
        vi. Washing station

   c. High End Equipment
      i. Dedicated equipment
      ii. Jacketed Addition Funnels
      iii. Meters
         1. pH meters
         2. pAg meters
         3. Viscosity meters
      iv. Duplex Safelights
3. Coating
   a. Basic Equipment
      i. Brushes
   b. Intermediary Equipment
      i. Airbrush Systems
      ii. Emulsion Coating Blades
   c. Small Scale Production
      i. Trough coating systems
      ii. The Australian job

<u>Review of Facilities [0.33 Hours]</u>

1. The Ideal Space
   a. Emulsification Room
   b. Coating Room
   c. Storage
   d. Testing
2. Inspection of our space

<u>Emulsion Making [3 Hours]</u>

1. Preparing all equipment & facilities for emulsion making
   a. Darkroom etiquette
   b. Cleaning and sterilization of all labware
   c. Safelight check
2. Emulsification
   a. Preparation of stock solutions
      i. Handling of chemistry
      ii. Measurement procedures
   b. Bringing stock solutions to temperature
   c. Methods of addition
      i. Single Jet & Double Jet
      ii. Surface Addition & Subsurface Addition
   d. Duration of addition
3. Physical Ripening (a.k.a. Ostwald ripening)
   a. Formation of complex ions
      i. Excess halide (neutral emulsion)
         1. $AgBr_2$-, $AgBr_3$--, $AgBr_4$---
      ii. Ammonia [NH_3] (ammoniacal emulsion)
         1. $Ag(NH_3)_2$+
   b. Cannibalization
      i. Trending towards lower energy states
4. Washing

   a. “Noodling”
   b. Washing systems
5. Sensitization
   a. Chemical sensitization
   b. Spectral sensitization
6. Finals
   a. Surfactants
   b. Hardeners
7. Storage

Coating Emulsion [1 hour]

1. Preparation of the base for coating
   a. Subbing raw acetate leader
      i. Formulating a substratum layer
      ii. Coating the substratum layer
      iii. Advantages/Disadvantages
   b. Using “found footage”
      i. Methods for preparing fogged stock for coating
         1. Fix in hardening fixer followed by plain water rinsing
         2. Rinse in clearing bath followed by plain water rinsing
         3. Rinse in water with added surfactant
         4. Dry
      ii. Methods for preparing processed found footage (B&W) for coating
         1. Bleach in reversal bleach followed by plain water rinsing
         2. Rinse in clearing bath followed by plain water rinsing
         3. Rinse in water with added surfactant
         4. Dry
2. Coating methods
   a. Brushing procedures
   b. Airbrushing procedures
3. Small strip coating
   a. Plate systems
4. Long strip coating
   a. Looping system
   b. Non-looping systems

Dinner Break [0.66 Hours]

The Photochemical Process [0.33 Hours]

1. Some basic terms
   a. Reduction, Reducers
   b. Oxidation, Oxidizers
   c. Ions, Cations, Anions
   d. Photon, Electron, Positive Hole (or
   e. Halogen
2. The latent image
   a. Electrostatic balance of the silver halide crystal
      i. The perfect silver halide crystal
      ii. Dislocations

1. Edge dislocations

iii. Defects

1. Frenkel defects
    a. Interstitial silver ions

b. Photolytical reduction

i. Photon annihilation

1. Exciton
2. Electron Hole

ii. Sensitivity centers

iii. Formation of the latent image

1. Unstable latent image
2. Subimage latent image
3. Reducibility of the latent image
    a. Reciprocity failure
    b. Latensification
        i. Hypersensitization
        ii. Concurrent photon amplification

3. Amplification of the latent image (development)
    a. Catalytic reduction of the silver halide crystal
    b. Byproducts of development
        i. Bromide
        ii. Oxidized developer
4. Removal of excessive halides (fixation)
    a. Solubility of silver halides

<u>Testing the Emulsion [1.0 Hour]</u>

1. Simple contact printing procedures
2. Processing procedures
3. Sensitometry
    a. Fog
    b. Speed
    c. Stability

Day II [8 Hours]

This day will be dedicated to practical experimentation of emulsion chemistry...

<u>Emulsion coating [0.5 hours]</u>

<u>Daylight Photography [1.0 Hours]</u>

1. Photography of 100 feet of coated film
2. Processing

<u>Experiments and Creative Processes [1.5 Hours]</u>

1. Contact printing with a Bolex
2. Reticulation

<u>*Open Experimentation* [4 Hours]</u>

1. Emulsification

2. Printing
3. Etc

Exhibiting the results [0.5 hour]

Analysis [0.5 hour]

Following the Workshop

Documentation

1. Digital transfer of selected pieces
2. Adjustment of notes
3. Distribution of notes to workshop participants

Workshop Resources

Conversions

Surface Area of Motion Picture Film

S8mm x 100 ft. = 2.62 ft²
16mm x 100 ft. = 5.25 ft²
35mm x 100 ft. = 11.50 ft²

Temperature

[°C] = ([°F] − 32) × (5/9)
[°F] = ([°C] × (9/5)) + 32

Volume

Milliliter (ml) = Liter (L) * 1000.0
Milliliter (ml) = US Fluid Ounces (fl.oz) * 29.6
Milliliter (ml) = UK Fluid Ounces (fl.oz) * 28.4

Liter (L) = US Gallon * 3.79
Liter (L) = UK Gallon * 4.55

US Fluid Ounces (fl.oz) = ml * 0.0338
UK Fluid Ounces (fl.oz) = ml * 0.0352

UK Gallon = Liter (L) * 0.22
US Gallon = Liter (L) * 0.264

Mass

Grams (g) = Kilograms (kg) * 1000.0
Grams (g) = Ounces (oz.) * 28.35
Grams (g) = Grains (gr) * 0.0648
Grams (g) = Pound (lb) * 453.592

Ounces (oz.) = Grams (g) * 0.0354
Ounces (oz.) = Pound (lb) * 16

Grains (gr) = Grams (g) * 15.432
Grains (gr) = Ounces (oz.) * 437.5

Mass to Liquid Percentages

$M\ [g] = V_R\ [ml] * (\%_R / 100)\ [g/ml]$

Where $\%_R$ is the required percentage, V_R is the required volume in milliliters and M *is the mass of the dry ingredient in grams.* EXAMPLE: *You want 1 liter of a 10% solution of potassium bromide. Therefore...*

$$M = 1000\ ml * (10 /100)\ g/ml$$
$$M = 100.0\ g$$

Liquid Percentage Conversions

$V_S = (\%_R / \%_S) * V_R$

Where V_S is the volume of stock needed for dilution in, $\%_R$ is the required percentage, $\%_S$ is the stock percentage and V_R is the required volume. EXAMPLE: *You have 28% acetic acid, but the recipe calls for 100.0 ml of 3% acetic acid. Therefore...*

$$V_s = (3/28) * 100.0\ ml$$
$$V_s = 10.714\ ml$$

...thus, substitute the 100.0 ml of 3% acetic acid called for in the recipe with 10.714 ml of 28% acetic acid.

Emulsion Formulary

BE-1 (Unwashed Bromide Emulsion)[1]

BE-1 is a very simple and easy to make emulsion, requiring only the basics in terms of supplies, techniques and equipment. The emulsion is generally fine grain with an exposure index between 1 - 5, though this will depend on your choice of gelatin, among other things...

Technical Data	
Type	Emulsion (Bromide, Slow)
Approx. Shelf Life	3.00 months
Coating Capacity	+/- 25.00 ft^2
pH	--
Solution A	
Distilled Water	63.0 ml
Potassium Bromide [KBr]	8.0 g
Active Gelatin	10.0g
Solution B	
Distilled Water	63.0 ml
Silver Nitrate [$AgNO_3$]	10.0 g

1. PREPARATION OF STOCK SOLUTIONS. **Solution A** Add the potassium bromide to the distilled water and dissolve completely. Than, under constant agitation, slowly add the gelatin to the solution. Allow the gelatin to swell (approx. 20 minutes) and then slowly raise the temperature to 50 C. **Solution B** Dissolve the silver nitrate in the water and then slowly raise to 45 degree C
2. EMULSIFICATION. Emulsification should occur under a safelight (Kodak 1 or equivalent) or in complete darkness. Each solutions respective temperature should be maintained across the duration of emulsification. Begin by bring solution A to a rapid agitation followed by the addition of half of solution B (approx. 33 ml) across 30 seconds. Bring solution A to a rest and ripen for 15 minutes. Increase agitation of solution A to a rapid agitation followed by the addition of solution B across 10 minutes (approx. 3 ml/minutes).
3. RIPENING. Allow the emulsion to ripen at a temperature of 50 C for 20 minutes, without agitation.
4. WASHING. No washing is necessary for this emulsion.
5. SENSITIZATION. No additional sensitization required.
6. FINALS. Finals can be added at ones own discretion. Recommended additions would be 60.00 ml of Kodak PhotoFlo 2000, 10 ml of 10% chrome alum (fresh)

[1] Taken from Silver Gelatin: A User's Guide to Liquid Photographic Emulsions (Reed, Martin; Jones, Sarah - 2001) with modifications by Kevin Rice

Photochemical Formulary

Kodak D-19[2]

Designed as a continuous-tone developer for scientific and technical work, D-19 is a high energy (i.e. high contrast) developer well suited for black and white reversal processes, among others. D-19 has good keeping properties and a high capacity as well.

Technical Data	
Type	Developer (MQ based, High Energy)
Approx. Shelf Life	3.00 months
Capacity	+/- 30.00 ft² per. 1,000.00 ml
pH	11.0
Stock Solution	
Water @ 52.0 C	750.0 ml
Metol [$C_7H_9NO \cdot 1/2H_2SO_4$]	2.0 g
Sodium Sulfite, Anhydrous [Na_2SO_3]	90.0 g
Hydroquinone [$C_6H_4(OH)_2$]	8.0 g
Sodium Carbonate (Anhydrous) [Na_2CO_3]	45.0 g
Potassium Bromide [KBr]	5.0 g
Water to make...	1,000.0 ml

1. MIXOLOGY.
    a. Measure out each constituent separately before proceeding.
    b. Bring water to temperature and dissolve a pinch (approx. 5.0 g per liter) of the sodium sulfite to the solution.
    c. While agitating the solution, dissolve each constituent in the order that they appear in the table above, making sure that each one is dissolved in it's entirely before the next addition.
2. STORAGE. Store the final stock solution in an airtight container. Protect from light when possible.
3. DILUTION. Generally speaking D-19 is used undiluted. Dilution can be used to certain effects, but experimentation would need to be undertaken.
4. RECOMMENDED DEVELOPING TIMES. As always, developing times vary based on a considerable number of factors. The times below are simply starting points for experimentation using the undiluted stock solution...
    a. 1 EI ~ 2.00 minutes
    b. 25 EI ~ 3.00 minutes
    c. 100 EI ~ 5.00 minutes
    d. 200 EI ~ 6.5 minutes

[2] Taken from Photographic Lab Handbook, 5th Edition (Carroll, John S. - 1979)

HF-1 (Hardening Fixer)[3]

This formula is a composed of plain hypo with a diluted quantity of F-5a Hardener.

Technical Data	
Type	Fixer (Hardening, Acidic)
Approx. Shelf Life	*indefinite*
Archival Working Capacity	+/- 50.00 ft² per. 1,000.00 ml
pH	--
Stock Solution	
Water @ 52.0 C	750.0 ml
Sodium Sulfite, Anhydrous [Na_2SO_3]	19.0 g
Sodium Thiosulfate [$Na_2S_2O_3$]	240.0 g
Boric Acid, Crystals [H_3BO_3]	9.0 g
Potassium Alum, Dodecahydrate [$KAl(SO_4)_2.12(H_2O)$]	19.0 g
Acetic Acid (28% Solution) [CH_3COOH]	60.0 ml
Water to make...	1,000.0 ml

1. MIXOLOGY.
    a. Measure out each constituent separately before proceeding.
    b. Bring water to temperature and, while agitating, each constituent in the order that they appear in the table above, except for the acetic acid.
    c. Reduce the temperature of the solution to approx. 20.0 C and add the acetic acid slowly.
2. STORAGE. Protect from light when possible.
3. DILUTION. Diluting is not recommended for standard fixing procedures.
4. RECOMMENDED FIXING TIMES.
    a. All stocks ~ 7.0 minutes

[3] From Kevin Rice

CB-1 (Clearing Bath)[4]

CB-1 is a very basic formula for a clearing solution.

Technical Data	
Type	Rinse (Ionic)
Approx. Shelf Life	indefinite
Archival Working Capacity	+/- 200.00 ft² per. 1,000.00 ml
pH	--
Stock Solution	
Water @ 52.0 C	750.0 ml
Sodium Sulfite, Anhydrous [Na_2SO_3]	100.0 g
Sodium Bisulfite [$NaHSO_3$]*	25.0 g
Water to make...	1,000.0 ml

**The sodium bisulfite was originally included in this formula to act as a buffer for the solution as it was found that an unbuffered solution lead to excessive swelling of emulsions. However, given today's emulsions, this may not be as significant of an issue. Therefore, it is perfectly safe to exclude this constituent from the formula if needed.*

1. MIXOLOGY.
    a. Measure out each constituent separately before proceeding.
    b. Bring water to temperature and, while agitating, each constituent in the order that they appear in the table above.
2. STORAGE. Protect from light when possible.
3. DILUTION. A dilution of 1:9 (i.e. 1 part stock to 9 parts water) is recommended. Discard immediately after use.
4. RECOMMENDED CLEARING TIMES.
    a. All stocks ~ 1.0 minute

[4] From Kevin Rice

R9 Reversal Bleach[5]

This formula is a dichromate based, reducing bleach. It is the most commonly quoted formula for use in reversal processing. Additionally, it is a useful cleaner of labware. However, the formula is highly toxic.

Technical Data	
Type	Bleach (Reducer), Dish Cleaner
Approx. Shelf Life	*indefinite*
Archival Working Capacity	+/- 200.00 ft² per. 1,000.00 ml
pH	--
Stock Solution	
Water @ 20.0 C	750.0 ml
Potassium Dichromate ($K_2Cr_2O_7$)*	9.5 g
Sulfuric Acid, 100% (H_2SO_4)**	12.0 ml
Water to make...	1,000.0 ml

**Carcinogenic compound: Always handle with full body, eye and respiratory protection.*

***Concentrated acid: Always handle with full body and eye protection. Never add water to acid -- always add acid to water.*

1. MIXOLOGY.
    a. Measure out each constituent separately before proceeding.
    b. While agitating, add each constituent in the order that they appear in the table above.
2. STORAGE. Protect from light when possible.
3. DILUTION. Diluting is not recommended.
4. RECOMMENDED BLEACHING TIMES.
    a. All stocks ~ 2.0 minutes

[5] Taken from Photographic Lab Handbook, 5th Edition (Carroll, John S. - 1979)

Filmmakers and Selected Works

While there is a strong interest in the use of handmade emulsion, there is a relatively small amount of work being produced

- Ben Donahue [researcher]
- Alex Mackenzie (http://www.alexmackenzie.ca/)
  - *Logbook* (2011)
  - Various performances
- Lindsay McIntyre
- Robert Schaller (http://www.robertschaller.org/)
  - *Triptych* (1996) [Gum Bichromate Emulsion]
  - *If Not One and One* (1999) [Gum Bichromate Emulsion]
  - *To the Beach* (1999) [Gum Bichromate Emulsion]
- Esther Urulus (http://estherurlus.hotglue.me/)
  - *Konrad & Kurfurst* (2014)

Chemical Suppliers

- ArtCraft Chemicals (http://www.artcraftchemicals.com/) -- *New York based photochemical supplier with a good selection and good prices, particularly for silver nitrate.*
- Photographers Formulary (http://stores.photoformulary.com/) -- *Montana based photochemical supplier with a moderate selection and good prices. Also sells kits and books.*
- Nymoc Products Co. (https://plus.google.com/111988851146358298635/about?hl=en) -- *Toronto based chemical supplier with the widest selection at the highest cost.*

Literature

The following selection of literature is a comprehensive list of text relating to the workshops subject matter. Highly recommended text for those looking to go in depth with the subject have been marked with an asterisk. Additionally, any hyperlinked text are available to download from Process Reversals website at http://processreversal.org/literary-resources/

- Emulsion
  NOTE: It's important to understand that any literature dealing with emulsion published before the 1940's assumes the use of photograde ACTIVE gelatin, which is no longer produced. Everything following that assumes the use of inert gelatin.
  - *Photographic Emulsions* (Wall, E.J. - 1929)
  - *Modern Dry Plates* (Eder, J.M. - 1881)
  - *Photography with Emulsions* (Abney, William De W. - 1885)
  - *The Photographic Emulsion* (Carroll, B.H.; Hubbard, D.; Kretschman, C.M. -1934)
  - *Photographic Emulsion Technique* (Baker, T. Thorne - 1941)*
  - *The Theory of the Photographic Process* (Mees, C.E. Kenneth - 1942)
  - *Photographic Emulsion Chemistry* (Duffin, G.F. - 1966)*
  - *Photographic Sensitivity: Theory and Mechanisms* (Tadaaki, Tani - 1995)*
  - Dye Transfer Materials (Browning, James - 1998)
  - *Silver Gelatin: A User's Guide to Liquid Photographic Emulsions* (Reed, Martin; Jones, Sarah - 2001)
  - *Making, Coating and Processing a Simple Gelatin Emulsion* (Osterman, Mark - 2007)
  - *Photographic Emulsion Making, Coating & Testing* (Mowery, Ron - 2009)
  - *Making Kodak Film* (Shanebrook, Robert L. - 2012)
  - *Re:inventing the Pioneers: Film Experiments on Handmade Silver Gelatin Emulsion* (Urulus, Esther - 2013)*
- Sensitometry
  - *General Sensitometry* (Gorokhovskii, Yu. N.; Levenberg, T.M. - 1965)
  - *Photographic Sensitivity: Theory and Mechanisms* (Tadaki, Tani - 1995)
- Photochemistry

- *Motion Picture and Television Film: Image Control and Processing Techniques* (Corbett, D.J. - 1968)*
- *Developing: The Negative Technique* (Jacobson, C.I.; Jacobson, R.E. -1976)
- *Photographic Lab Handbook, 5th Edition* (Carroll, John S. - 1979)
- *The Film Developing Cookbook* (Tropp, Bill; Anchell, Stephen G.-1998)*
- *The Darkroom Cookbook, 3rd Edition* (Anchell, Stephen G. - 2009)*

- Artist Run Film Labs
  - *Kinetica: Lieux d'Experimentations Cinematographiques en Europe* (Gran Lux - 2011)

Web Resources

- APUG.org
  - Forum: Silver Gelatin Based Emulsion Making & Coating
    - Homemade Film Coating Machine
  - Anything posted by Ron Mowery (Photo Engineer)
- thelightfarm.com
- filmlabs.org
- graphicsatlas.org