DARKROOM

How to Process Holographic Film and Plates

INITIALIZING YOUR BOX

All the small holographic plates are facing the same way in the white plastic rack inside the black lightproof box. But which way are they all facing? Emulsion this way or that way?

Upon opening a box the first time, I check it to see which is the coated side with either the taste test, wherein the lips are moistened, then applied to the holographic plate, and the side that sticks to the lips is the coated side, while the plain glass side will remain slippery, or the breath test. The reflection of a safelight, (and I do mean **safe**light) is observed on the plate. The plate is then breathed upon. If the glass side is breathed on, condensation will form on the surface, rendering the reflection diffuse and fuzzy. On the coated side, the sponge-like gelatin binder of the light sensitive coating will absorb the humidity of the exhalation, and will not fog up. Once you find the coated side, replace the test plate back in the rack, and let it dry out and cool down before using it to record a hologram, as even these slight stresses may not allow a hologram to be recorded as the plate would be changing its dimensions until it stabilizes.

The label on the lower half of the Agfa light tight box serves as a landmark as to the orientation of the plates. (Whereas Ilford boxes have the label on the removable top, whose orientation is independent of the rack with the plates.) My own standard is to place the coated side toward the label, the uncoated side towards the unlabelled side. You could adapt that for your own, or the contrary one. Once the coated side is found, the rack can be lifted out of the black bottom and repositioned if necessary to conform to the standard.

The boxes and racks for the 2 1/2 inch square plates and 4 by 5 inchers are from EMPAK, and wholesale for $8.05 and $10.85, respectively. The biggest boxes that they make hold plates up to 7 inches square, but it would be nice if they would bring out something for the 8 by 10 inch or 30 by 40 cm.

Carriers are provided with wash slots on sides to facilitate efficient washing, drainage, and drying of photoplates, masks and similar substrates. End walls have receptors for EMPAK handles or robotics/automation effectors.

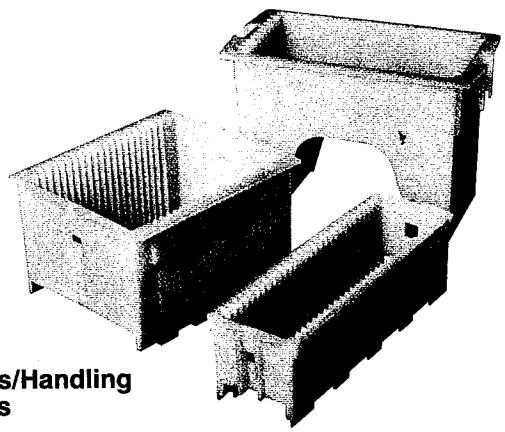
Process carriers are molded of:

- Tefzel (ETFE) natural -2615
- Polyvinylidene fluoride (PVDF) natural -0415

Handling/shipping carriers are molded of:

- High density polyethylene (HDPE) natural -1715
- Polypropylene (PP) natural -6015

-#### Designates material/color to be inserted as the suffix to the part number when placing order.



Process/Handling Carriers

Boxes accept carriers for protective handling/storage or shipment. Boxes have a snap-lock cover and are stackable. Cushions attach to the inside of the box covers and eliminates movement of photoplates, masks and similar substrates during handling and shipment.

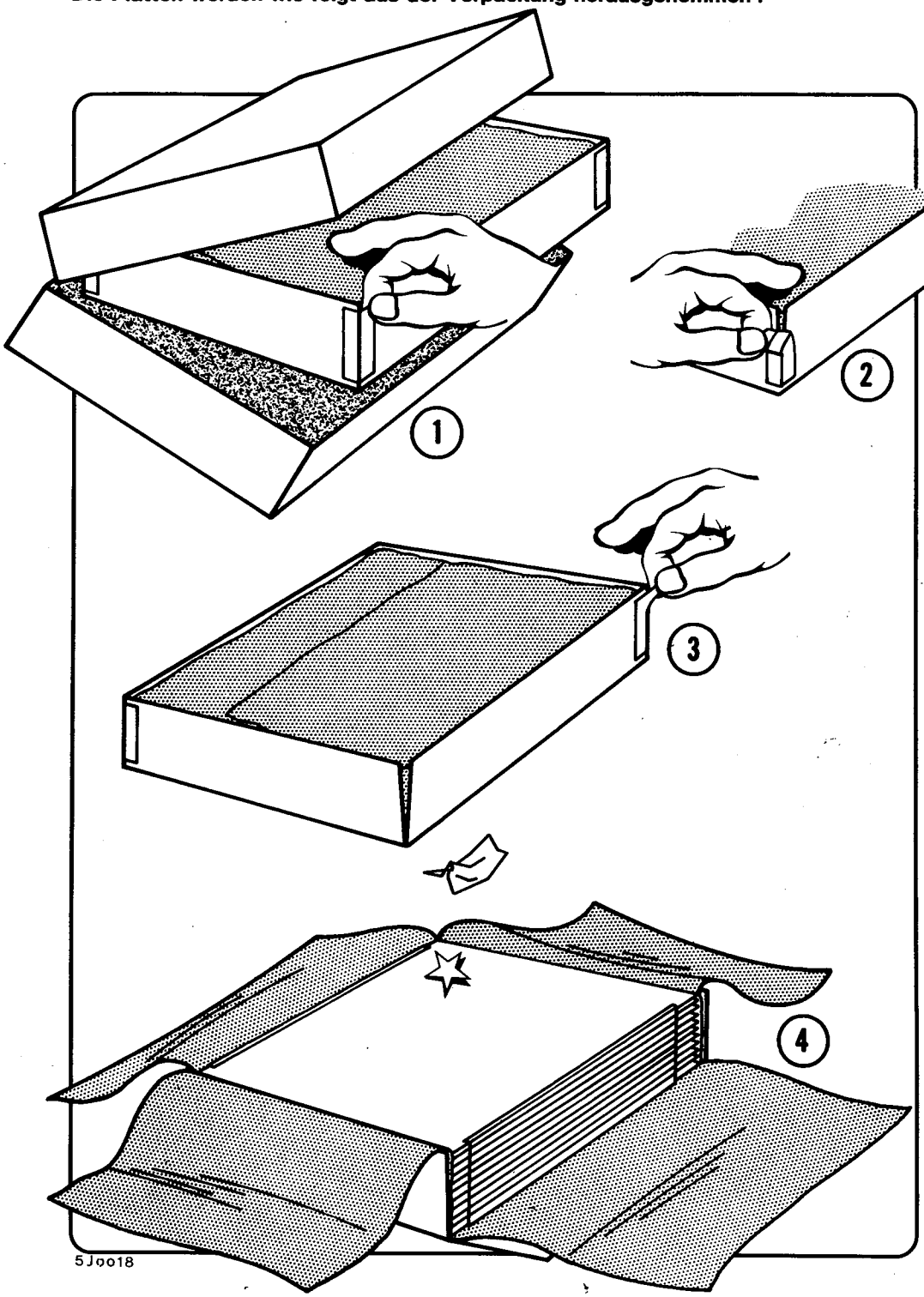
- Mask handling/storage/shipping boxes are molded of medium impact polystyrene (MIPS) black
- Cushions are molded of low density polyethylene (LDPE) natural

Handling/Storage/ Shipping Boxes

EMPAK®

1501 Park Road
Chanhassen, Minnesota 55317
TEL (612) 474-5282
TWX 9105762775

Om de platen uit de verpakking te nemen gaat men als volgt te werk :
Pour retirer les plaques de l'emballage on procédera comme suit :
In order to remove the plates from the packaging one should proceed as follows :
Die Platten werden wie folgt aus der Verpackung herausgenommen :



The 8 by 10 inch and 30 by 40 centimeter holographic plates are packed in three piece cardboard boxes for better lighttightness. Every other plate has a plastic runner on it, so that the plates are stacked on top of each other without touching. Even so, there is a too high percentage of these plates which are broken in transit.

When the box is in this orientation, the coated sides are facing down on all the plates except for the bottom one, where the emulsion side is up!

AGFA

Holotest film follows the convention of photographic film insofar as identification of emulsion side by providing a code notch that if positioned in the upper right hand corner when the piece is held with the long side vertical, then the emulsion is facing up. However, once in a while these notches are not there! A taste or breath test may be used to tell which side is up, but generally the film curls with the coated side in.

STANDARD TEST OBJECTS

During the course of calibrating materials and set ups, standardized test objects are used. Here are a few examples.

SINGLE BEAM REFLECTION: Denisyuk style holograms can provide the most useful information about materials and their processing. Brightness, signal to noise, and fringe distortion evidenced by color shifting can be easily observed.

My standard test object for this hologram is a mold from a waffle iron, painted with high reflectivity **Krylon #1401 Bright Silver Spray Paint**. Three small steel balls are glued to the object and provide a plane for the plate to be placed directly on it. It is usually held between a pair of goal posts, tilted at an angle, so that horizontally travelling spatially filtered laser light will impinge on the test plate directly, without transfer mirrors to add dirt noise to the beam.

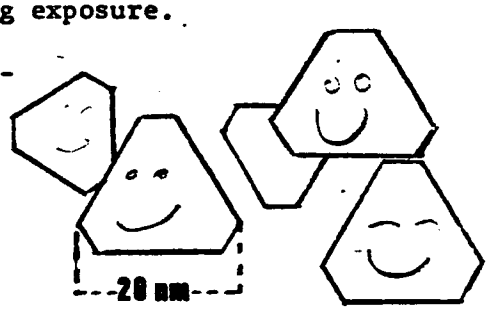
A piece of cardboard cut to the same size as the plate but with a quadrant or an eighth cut out of it is used as a mask to record a series of exposures on one plate. Because the waffle pattern is shallow and repetitive, each one of the test sections is exactly like the others.

This object has been used many times, so much so that I am getting sick of it, but keeping it the same allows one to compare results from years of studies. There is one at **SAIC, Lake Forest College** and of course my own home lab. **Agfa, Ilford,** and **Kodak** silver halide materials have been tested on it along with **DuPont** and **Polaroid** photopolymers and home-made dichromated gelatin.

PHYSICAL STRUCTURE

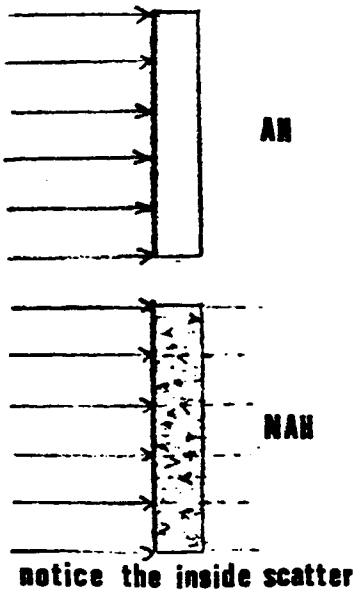
The light sensitive particles are suspended in a gelatin environment, hence the term emulsion. For holography films, this emulsion is between 5 and 15 microns thick, coated either on an acetate film support or on a glass plate. The film support is less than half a millimeter thick while glass plates are about one to two millimeters thick. The emulsion accounts for only one hundredth of the total thickness of the glass plate. The glass is dimensionally stable, but the film must be sandwiched between plates of glass to hold it in place and to prevent it from curling during exposure.

Inside the emulsion are the tiny, light sensitive silver halide crystals. They range in size from 20 nanometers to 50 nanometers and this classifies them as having a micro-fine grain structure. The crystals are composed of many millions of positive silver ions and negative ions of either bromine or chlorine in a hexagonal lattice. When light hits these crystals, a few (like one in 10 or 100 million) of the silver ions are changed into metallic silver. These crystals are now ready to be developed and they carry the latent image.



A problem with these micro-fine grained materials is that they "forget" their latent image with time. For instance, Kodak Holographic Plate SO-120 loses 20% of its latent image to decay if developing is postponed for an hour. This is typical of all present day holographic materials.

Other junk inside the emulsion are sensitizing dyes. Some of these dyes increase the sensitivity of the silverhalides to light in general, while others increase the sensitivity to specific colors of light. Kodak High Speed Holographic Film SO-253 has a nasty blue dye dispersed throughout its emulsion that must be removed during processing in a methanol bath but gives the film its unusually high sensitivity.



Another type of dye put into the emulsion or more precisely, behind it, is the antihalation backing. This backing prevents light from scattering off the support material or the film holder back into the emulsion, fogging and ruining the interference pattern. For reflection holograms, the film cannot have the antihalation backing because the reference and object beams are coming from opposite sides of the film. So there is usually a choice between backed materials, (antihalation or AH for short), or unbacked (non-antihalation or NAH).

All these elements of the film or plate are very fragile. High humidity or temperature can ruin the light sensitive particles and can cause overall fog on the film. The crystals lose their sensitivity to light over time; that is why there is an expiration date on the package to ensure that the materials are used while they are still fresh and active. The gelatin emulsion can soften and fall off the support in hot water. The film support is either acetate or Estar, a proprietary polyester from Kodak, which is rather durable. But glass can easily break, and even though the holographic information is all over the plate, it is better to keep it all in one piece. Holograms should be stored in a cool dry place, preferably covered and framed or just overmatted. Silver, being a precious metal is often subject to major fluctuations in market value and the films and plates then follow suit. Possible replacements for this technology are being investigated right now; perhaps in the future silver halide plates will be to holography as the daguerreotype is to photography.

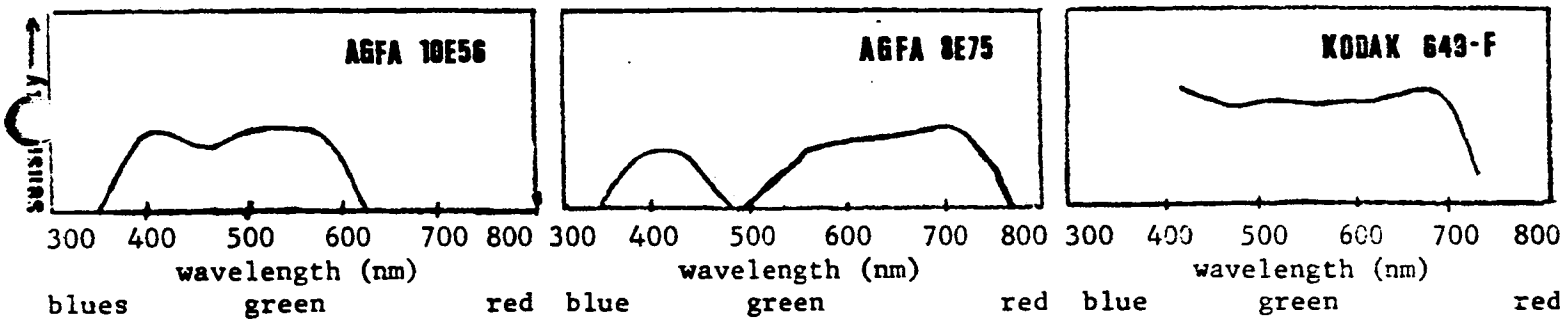
8/7/80 EW

SPECTRAL SENSITIVITY

A problem with silver-based technology since the days of early photography has been that the materials are inherently more sensitive to the higher frequencies of light (the short wavelengths in the blue end of the spectrum) because they carry the most energy. Blues and whites would photograph fine, but the greens and reds would come out relatively darker because the material was not responding to those colors. In the latter part of the nineteenth century, the discovery of introducing dyes into the emulsion which made the halides sensitive to green and red paved the way not only for black and white photographs with the colors in their natural tonal relationships, but also color photography as well as holography by Helium-Neon Laser.

Choosing a material for holography depends on its sensitivity to the color of the laser that is being used. Consulting a spectral sensitivity curve for the material in question will help make this decision as this is a graph of the relative sensitivity of the material to the different wavelengths. The vertical axis represents

SPECTRAL SENSITIVITY CURVES



relative sensitivity, the horizontal axis depicts the colors of the spectrum by wavelength. From looking at the above curves, the 10E56 emulsion is sensitive to blue and green light only, and is not suitable for making holograms with red lasers, but it can be handled under red safelights. 8E75 lacks green sensitivity, so a green safelight is used. This film was designed for holography with Helium-Neon and Ruby lasers. The Kodak Spectroscopic Plate 649-F is panchromatic -- it is sensitive to light of all colors. This material is extremely fine grained and was used in recording the earliest holograms of Leith and Upatnieks. Its slow speed makes its use prohibitive with small lasers but with its panchromatic sensitivity it can be used for recording full-color holograms.

8/7/80
EW

PROCESSING PROCEDURE

Organizing the chemicals, checking their temperature, and adjusting the safelights are good things to do after loading the **Holographic Material** in the set up while waiting for it to settle. Exposures can be made safely with water running in the sink. Just remember to be safelighted in the **Darkroom** when exiting into a safelighted **Lab**.

Don't forget about the **Infamous Lighting Chiasm***. The **Safelights** are in the sconce farthest from the door, but their switch is the one nearest the portal. The **White Lights** are on the near sconce, but the switch is the far one. It is also a good idea to make the **Safelights** safer by dimming them down about halfway.

DEVELOPER: The developers we use, **CWC2** and **Pyrochrome**, are stored in two parts to ensure longer shelf life. The **A** and **B** parts are mixed together in equal amounts before use. There is a poor old **500 mL Plastic Graduated Cylinder** whose sole reason for existence is to measure out the developer solutions. It has been stained a wonderful umber and should be used only for developer measuring. It is stored in the **Darkroom Sink**, filled with water to prevent a crusting of dried developer in it. There are marks on the **Plastic Graduated Cylinder** for the appropriate amounts of both **A** and **B** to be combined in the **Developer Tray**. For four by five plates developed in five by seven inch trays about 75 to 100 ml of each solution are necessary to cover the plate. 250 ml of each are necessary for an eight by ten inch tray; a half-litre of each for a 30 by 40 centimeter tray. Once mixed, the **CWC2 developer** will last for a complete lab session, especially in a covered tray. The **Pyrochrome**** **developer** will become useless after fifteen minutes, so mix the two parts for this one immediately before use, and dump it when done.

Check the developer temperature before immersing the hologram. Target temp is **75F (24C)**. If too cool, immerse in a bigger tray of hot water. Don't put a plastic tray on the **Hot Plate/Stirrer** to warm it up. Warm a little water in a glass beaker to provide heat for the water bath. **DON'T** mess with the sink's temperature stabilizer, as it takes a while to stabilize. To

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*. Chiasm, from the Greek letter chi, X, usually means a criss-crossing.

. **Pyro Developer Part A is usually not kept mixed on hand because of its short shelf life. The formula is simply 10g/L **Pyrogallol**, the jar of which is kept on the **Chemistry Shelf**. For more details, see the **Handout, PYROCHROME**.

cool, place in a water bath of cold water. A small tray of ice cubes is in the **Little Refrigerator**; they are not to be used for anything other than developer temperature control. If they melt, please don't forget to fill the tray for the next holographer.

There are three thermometers in the **Holographic Darkroom**, and they all disagree. The **Weston Dial Thermometer** is the authority, and is used to measure the solutions in the trays. Our procedures are calibrated to this item. Please be gentle with it, and return it to the film drying wire high over the sink. Another place it migrates to is inbetween some vats of chemicals.

The temperature of the water wash is controlled by the **Thermostatic Water Control**. It is an erratic performer and cannot be trusted. Let it run for a while, and note the temperature on the dial. The target on its thermometer is an indicated 78F, to provide a water bath that will keep the developer at 75F. Follow the directions on the knob to increase or decrease the temperature.

The third thermometer is in-line, after the **Water Pressure Knob**. Just enjoy how scientific it looks.

Putting a plate upside down in a tray can cause disaster, from no developed areas at all in a flat-bottomed tray to unsightly artifacts from the rib patterns in the other kinds. Scratches are avoided with the emulsion up, too. Always check to see which way is up!*

SLIDE the hologram into the liquid starting with one edge. This insures even wetting of the coating. Dropping the plate into the bath causes uneven streaking from splashing.

Process for the recommended time. Use the **GRA-LAB 520** to do the timing. The **Red Sliding Switch** in the lower right-hand corner turns it on; push buttons under the approriate units control the count. Don't forget to turn it by punching the furthest right push-button when immersing the hologram in the developer. By adding 5 seconds to the developer time you can fire the timer first, let it count down to the :00 and immerse the hologram.

Timetables for development are recommendations, but sometimes conditions do not warrant strict adherence. A simple rule of thumb is to develop one minute for every five seconds that it takes until the hologram starts to darken. If it takes 10" before the film shows any density, finish development at 2 minutes; 5" then is 1 minute, 15" gives 3 minutes, etc.

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*. See the **Handout, INITIALIZING YOUR BOX.**

Developing to density may be more useful. Unbleached holographic test series are in the **Darkroom** to compare to the developing hologram. Notice that the optimum density for holograms to be bleached with a **Rehalogenating Bleach** is darker than that for those destined for a dunk in a **Silver Solvent Bleach**. The digits of the **Darkroom Timer** should be just barely visible through the properly developed hologram.

The **Developer Tray** should be **CONSTANTLY AGITATED**. Holographic recording materials are traditionally insensitive, and their developers are high energy. By continually cycling the used developing agents out of the emulsion so that they can be replaced by fresh ones ensures the best contrast of the recorded fringe system. This **Agitation** does not have to be violent; simply rocking the tray so that there is a smoothly flowing wave on the surface of the solution is all that's necessary.

WASH: Drain the developer from the hologram during the last 5 - 10 seconds in that step, and place in the **Special Washing Tray**, which has holes drilled along one side for drainage. The running water is delivered to it via a hose from the **Temperature Controlled Faucet** in the sink. The water should be about developer temperature (75F, +- 5F or **24C, +-3C**); too cold could reticulate the gelatin coating of the plate, resulting in a strange surface texture on the hologram and a distorted image. Too hot and the gelatin will shift, again resulting in a distorted image.

The hologram's emulsion will feel slippery when it first comes out of the **Developer**. This wash removes the **Developer**, and when the slippery developer is gone the coating will be ready for the **Bleach**.

BLEACH: Decide on which one you want to use*, find the right trays, and pour it out. Don't hold the tray up to the spigot of the storage container; solution might splash into your eyes. Use one of the **Specially-marked Beakers with Handles** to transport the bleach. Don't use these **Beakers** for anything other than this purpose. There is no need to mix anything. Bleach until clear, with gentle agitation, plus another 15 seconds to make sure everything is done.

The room lights may be switched on at this point.

WASH: For five minutes in running water. The sensitizing dye of Agfa Holotest 8E75HD emulsions acts as an indicating dye and

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*. See the Handout, **DEVELOPER-BLEACH COMBINATIONS**.

changes its color from cyan to pink in the acid rehalogenating bleach solution. When the hologram's color has changed back to its original out-of-the-box appearance, this washing step is complete.

However the silver solvent bleach either destroys the dye or renders it colorless. The emulsion takes on a pale yellow color in this bath, and is done washing when the hologram is colorless.

BLOOD BATH (OPTIONAL FOR REFLECTION HOLOGRAMS): Pour out some **Blood Bath** in its tray, place the hologram in it, and set under the **Blood Bath Lights**. Turn the lights on, watch the plate turn dried-blood red in 1 to 2 minutes, drain, and wash for 3 to 5 minutes.

PHOTO-FLO: Fill the Photo-Flo tray with the solution out of the storage tank, no mixing or additives, for one minute. Drain and transfer to the **Drying Cabinet**.

DRYING CABINET: Hot-air drying speeds things up. The toggle switch on the **Cabinet** is down for **Low** and up for **High** temperature. Turning the **Dryer** on is done by rotating the **Timer Switch**. Drying should be finished in five minutes.

WHEN DONE, pour the chemicals down the drain, unless someone else is going to use them next. (It's fun to watch what happens when Developer and Bleach mix!) Rinse the trays, and stack them properly to keep them clean and happy!

THE CASE FOR GLOVES

The developer is a brew called **CWC2**. It can leave brown or black stains on your fingers if you get them in there. The use of gloves is recommended. We have a supply of **Disposable Gloves** for this purpose. The important thing to note about gloves is to rinse them thoroughly after immersing them in any bath, just like you would do with your hands, to avoid cross-contamination*.

We have two types of bleaches. The bluish-colored one, called **Rehalogenating** or **Jeff Blyth's Copper Sulfate** or simply **Copper Sulfate Bleach**, has nothing which is toxic in it for the hands. However, it will sting if it enters a cut as it has **Acetic Acid** in it. The other bleach, the yellow one, called **Reversal Bleach, Shrinking Bleach, 'Chrome Bleach, or Silver Solvent**, does contain a nasty, namely potassium dichromate. It is a suspected carcinogen. Continued contact could result in chrome sores or ulcers on your skin. It too, can sting if it enters a cut.

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*. See the **Handout, TRAYS.**

The **Reddeveloper** or **Blood Bath** is simply Vitamin C in water. Nothing could be healthier. You could drink it, but you would get a tummy ache since it is an acid solution and will upset the pH balance of your stomache, resulting in heartburn. (Vitamin C tablets sold in stores are mostly starch to buffer the acid when it reaches the digestive tract.) It too will sting in open cuts.

Photo-Flo is gentle to the hands, but would result in a nasty case of diahrrea if swallowed. Taking the gloves off before pulling the hologram out of this solution would prevent contamination of this bath.

HOLOGRAM PROCESSING SCHEDULE

#1. DEVELOP.
RECOMMENDED DEVELOPMENT TIMES @ 75F:

MATERIAL	USE	TIME
AGFA 8E75HD PLATES	REFLECTION	TWO MINUTES
AGFA 8E75HD FILMS	REFLECTION	ONE MINUTE
AGFA 8E75HD PLATES	TRANSMISSION	FOUR MINUTES
AGFA 8E75HD FILMS	TRANSMISSION	FOUR MINUTES

FOR EITHER **PYROCHROME** OR **CWC2** DEVELOPERS.

#2. WASH 2 TO 3 MINUTES IN RUNNING WATER.

#3. BLEACH - UNTIL CLEAR PLUS 15 SECONDS IN **'CHROME BLEACH.** (the yellow-orange one)
- ONE AND ONE-HALF TIMES THE CLEARING TIME IN THE **COPPER SULFATE BLEACH.** (the blue-green one)

ROOM LIGHTS MAY BE TURNED **ON** WHILE HOLOGRAM IS IN THE BLEACH.

#4. WASH 3 TO 5 MINUTES IN RUNNING WATER.

#5. PHOTO-FLO FOR 1 TO 2 MINUTES AND DRY.

or

#5. REDDEVELOP (OPTIONAL FOR REFLECTION HOLOGRAMS)
Place hologram in a tray of **REDDEVELOPER** (**BLOOD BATH**) solution for **FOUR MINUTES.** Turn Floodlights over the Tray on after the hologram has been soaking in the bath for thirty seconds to avoid streaking. Discard **REDDEVELOPER** after each use.

#6. WASH 3 TO 5 MINUTES IN RUNNING WATER.

#7. PHOTO-FLO FOR 1 TO 2 MINUTES AND DRY.

CLEAN UP!
DUMP USED DEVELOPERS DOWN THE DRAIN AND RINSE THE TRAYS! RETURN THE BLEACHES TO THEIR BOTTLES UNLESS THEY LOOK POLLUTED! RETURN PHOTO-FLO TO ITS BOTTLE UNLESS POLLUTED! RINSE ALL TRAYS!

DEVELOPER - BLEACH COMBINATIONS

CWC2 DEVELOPER	+	REHALOGENATING BLEACH*	1' to 4' @ 20°C	Non-shrinking regimen keeps the replay color of reflection holograms exactly the same color as the laser's. Can be used for image-planing, contact copying, or real-time reflection interferometry. For laser transmission gives excellent brightness and S/N ratio with replay angle same as the recording reference angle. For white light transmission the blusih scatter may be objectionable for those who seek that perfectly clear window aesthetic.
CWC2 DEVELOPER	+	SOLVENT BLEACH	1' to 4' @ 20°C	Yields orange to green reflection holograms depending on developed density. - more density gives shorter wavelength replay. Shrinkage can cause change in reference angle for transmission holograms. Plate is totally clear after process.
PYROCHROME DEVELOPER	+	SOLVENT BLEACH	1' to 4' @ 20°C	Yields red to green reflection holograms depending on developed density similar to the above. Some change in reference angle for transmission holograms. Holograms have characteristic tan color, which helps reduce grain noise. Tan color can be removed with S-13 Stain Remover.
PYROCHROME DEVELOPER	+	REHALOGENATING BLEACH		Not recommended.

*CWPBQ2, Jeff Blythe's Copper Sulfate Bleach, or Nick Philips' Benign Bleach

EW 1/29/89

TRAYS

Trays are the most common processing containers. They can be bought in a camera store, or can be anything at hand that serves the purpose, like baking dishes.

When buying trays, get two for each chemical, one to hold it, the other to rest on top as a cover to prevent contamination from drops falling from films being moved from one tray to another and dripping into the wrong bath and oxidation from exposure to the air. Developers last much longer that way, and you can even get a whole day's worth of use out of **Pyrochrome** developers with this trick.

Trays sold in photo shops are either plastic or stainless steel. Plastic may break, whereas stainless steel is indestructible from that standpoint, but it can be attacked by the chemistry, most notably dichromate-based solutions like **Silver Solvent Bleaches** or DCG-sensitizing baths and **Copper Sulfate Bleaches**. Since plastic is so much cheaper, they are the most common choice, especially if two trays are dedicated to each type of processing chemical. Metal trays with baked enamel finishes were once quite common, but that coating has almost disapeared. The enamel was almost impervious to any photo-chemical, but if it were scratched or rubbed off, the metal underneath would rust or corrode very quickly. Glass, especially Pyrex, like baking trays are also good choices for processing solutions, but cooking sizes aren't the standard photographic sizes, plus the risk of shattering is high.

There are three choices in tray bottoms: flat, raised ribs, or depressed ribs. Flat bottoms need the least amount of chemistry, but glass plates can get stuck to the bottom of the tray thanks to water pressure, and could be next to impossible to remove at a critical time. Raised ribs prevents sticking, and then there are quite a few milliliters of solution under the plate or film. This is good since heavier by-products of the solution, like in fixers or solvent bleach, can congregate there, and not bother the surface of the material. Only with an expensive developer could it be considered wasteful. But if agitation is vigorous, they could scratch plastic film base. Depressed ribs make good catch basins for the pollutants, and don't allow glass plates to get stuck on the bottom.

After the trays are brought home from the store, they should be immediately marked with their intended usage, and whether it is the container or the cover for that solution. Chemicals can hide in cracks and not get properly washed out, polluting the solution that gets used in the tray the next time. But if it is

the same type of bath time after time the effect is negligible; but carryover can be fatal.

When storing the trays, make sure the top is in the corresponding bottom, as the worst that could happen is that the mating parts would infect each other with the same pollutants. And then the outside of another chemical's bottom fits into the inside of another's top, so whatever pollution would occur does not affect the working surfaces.

Developer trays will build up brown oxidation stains from used up developer hiding in the cracks, which is harmless, but they can be removed by letting Laundry Bleach sit in it. Sometimes (especially in the case of photographic paper developers), silver will precipitate out of the developer and coat the bottom of the tray. This junk can be wiped off or removed by a silver solvent solution, essentially a concentrated form of the **'Chrome bleach.** For this reason there are separate trays for photographic and holographic developers. (The **Photographic Trays** in the **SAIC Holographic Darkroom** are identified by their bright colors.)

There should be different trays for the two different types of **bleaches**, rehalogenating and solvent. If bromide ions from a rehalogenating bleach are put into the typical potassium dichromate solvent bleach, they will cause salts to be formed, rehalogenating the dissolved silver crystals as they are carried away in the bleach solution and forming a hard to remove white scum on the surface of the hologram. This scum will also form on the tray that a silver solvent bleach is used in, and can be removed by soaking in laundry bleach. Trays used for **PBQ*** bleaches will build up brown oxidized stains, again removable by **Laundry Bleach.** But the pink stain of phenosafranine, the optional desensitizing ingredient in **GP-431****, seems to mark the tray for life. The dichromate bleaches will also oxidize stainless steel, so go with plastic trays only for this bath, or don't allow the bleach to sit in the stainless steel for very long.

The developer is least tolerant of pollution by other baths. Bleach in developers will slow their activity thanks to the pH change and the addition of restraining bromine ions. Fixer in developer encourages the formation of dichroic fog, a white scummy powder that is not removable at all. Since fixers dissolve silver halides, a bleached hologram should never go near a fixing bath as the material which contributes to the modulation

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*. A nasty-smelling bleach bath, not used at SAIC.

**. A seldomly used formula nowadays.

c Ed Wesly

of the layer would be removed. For this reason fixer in bleach is not such a good idea.

Developer in a bleach bath will raise the pH and cause a slowdown of activity, and since its job is to reduce transparent silver bromide to black elemental silver, enough carryover might turn the bleached holo back into a dark one. The bleach can tolerate a few drops of developer, but it is best to start with a fresh batch.

A little bit of bleach in the fixer won't hurt things too much, as they are both acid solutions, and the addition of extra salts will just use up the fixer faster. Developers work only in alkali environments, and will be rendered inactive in the acid fixer and not be able to develop any salts that are in the fixer solution, but it will weaken the strength of the bath.

The last step, the wetting agent, is the most vulnerable and the worst one to contaminate. Any developer in there will start developing the silver halides in the plate, which could be repaired by rebleaching in a rehalogenating (not reversal) bleach. Bleach spillover would be more benign except that it could leave a stain in the emulsion until it were rewashed. As usual even a little fixer will be disastrous, as it will dissolve out the AgX, leaving nothing in there to diffract the light.

The moral of the story is: Always keep the trays covered to prevent contamination from splashing.

ANNOUNCING

DARKROOM-AIDS-FILM-DRYING-CABINET

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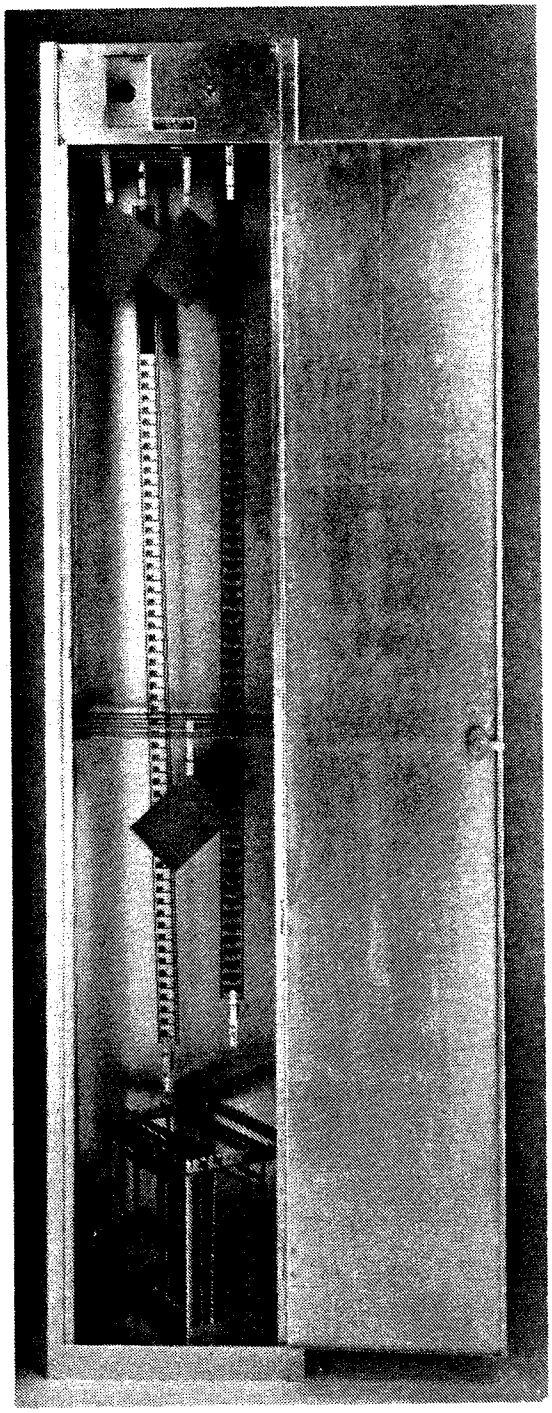
3449 North Lincoln Avenue • Chicago, Illinois 60657
312-248-4301 • Fax 312-248-5109



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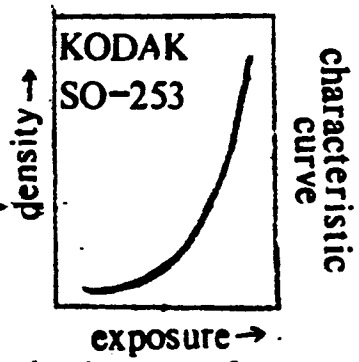
DENSITY

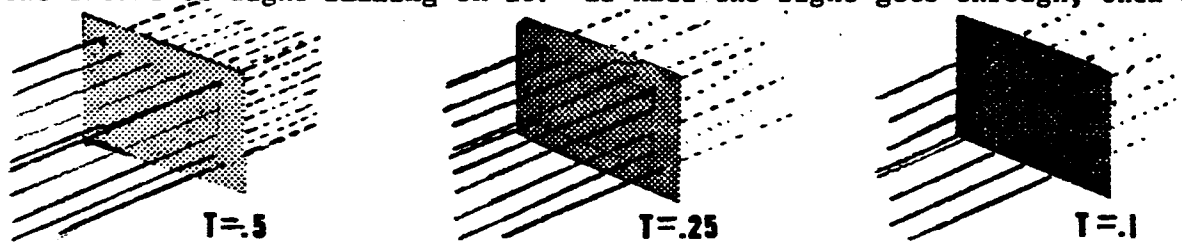
Density is a term used to measure how dark a transparent object is. The lower the number, the lighter and more transmissive the object is, and the higher the number the darker it is. The system is logarithmic; density of 2.0 is not twice as dark as 1.0 but ten times as dark. This scale is used because it is convenient in graphing the relationship of exposure to developed darkness in the characteristic curve of a silver halide based photosensitive material.



The most important idea to know about density is when to use it. Holograms are developed to match different densities for different applications, like usually .8 density for transmission, 1.0 or 2.0 for reflection holograms. Using a standardized calibrated step wedge for comparison will help when developing holograms by inspection.

Density is defined as the logarithm of opacity which is the inverse of transmission. Don't panic -- here are the terms one step at a time.

TRANSMISSION is the ratio of light that passes through an object to the to the amount of light falling on it. If half the light gets through, then the



transmission is ½ or .5 or 50%. If one fourth the incident light gets through, then transmission = ¼ = .25 = 25%; one tenth of the light passing through gives transmission of 1/10 = .1 = 10%.

OPACITY is the inverse or reciprocal of the transmission. Transmission of 50% or ½ means opacity of 2, while transmission of 10% or 1/10 would equal an opacity of 10.

DENSITY takes the opacity number and changes it to a logarithm of base 10. An opacity of 10, (which was a transmission of 1/10), changed to density is $\log_{10}10 = 1.0$. A transmission of only 1% or 1/100 is opacity of 100 which then becomes density of 2.0 because $\log_{10}100 = 2.0$.

To change a transmission of 25% to a density on a pocket calculator you would first enter .25, push the inverse button, 1/x, to get the opacity, (display will show 4), then punch the log x key. You should get the density of .60205999 which rounds to .6. Try completing this table.

TRANSMISSION	OPACITY	DENSITY
.1		
.3		
.5		
	8	
100%		

PYROCHROME

The **"Pyrochrome"** process was first brought to my attention by **Walter Spierings**, whom I met on a trip to the **Museum of Holography** in New York City in 1981. He was the Artist-in-Residence there, and was working on a three color rainbow transfer[1], but claimed that the processing he was using worked for both transmission and reflection. Most other holographers were skeptical that it would work for both modes.

His article on the process, "'Pyrochrome' processing Yields Color-Controlled Results with Silver-Halide Materials", was published in holosphere Volume 10, Numbers 7 and 8, p.1, (1981), and the display holography world became aware of it. The process had actually been described a few years earlier, by Ruud van Renesse[2], and had its roots in an even earlier paper by Kurtz and Lambert[3].

The process gets its name from the principal ingredients of the two baths in the process, the **Pyro** part from the developing agent, **pyrogallol**, and the **'Chrome** comes from the oxidizer in the bleach, **potassium dichromate.** There is a wash after each one of these solutions, and the final step is a soak in a wetting agent.

THE FORMULA for the developer is as follows:

PART A	**PART B**
10 gm pyrogallol	60 gm sodium carbonate
1 liter water	1 liter water

Developing time 1 to 8 minutes at room temperature.

What could be simpler? The **Part A** is the developing agent, which is activated by the mixing of an equal amount of **Part B**, which is the alkali, to it. The combined solutions will oxidize into uselessness in about 15 minutes.

Pyrogallol is one of the first photographic developing agents, having been described by Fox Talbot himself. It has two interesting properties; it can seek out silver halide crystals that have been exposed to light and reduce them to pure elemental silver, but also the by-products of that process tan the gelatin surrounding the grain. Holograms developed in this stew have a characteristic tan color, not unlike the tan color one finds under the black of leather jackets, which is not so surprising, as pyrogallol is used industrially to do just that, so watch it with the fingers in the developer, as it does tan living flesh! The brownness can be removed with a soak in laundry bleach. The tanning is beneficial in holography as it masks the grain scattering noise of the material, making this developer the

primary recommendation for the high speed holographic films like **Kodak Type 131/SO-253** or **Agfa 10E56** or **75** for bleached holograms.

Like any other developing agent, **pyrogallol** requires an alkali environment to do its job. **Sodium Carbonate**, ordinary washing soda, provides the proper **pH**, around 10.6. But once the pyro is in the alkali, it is very susceptible to oxygen in the water, and turns black as the oxygen atoms break into the long organic chain. Mixed solutions of **A** and **B** will last an hour at least, but it's at its freshest in the first 15 minutes. Even covering the developer tray with another just slows down the process so that the developer should be replaced in an hour or so.

The second **Pyrochrome** article in holosphere was written by Graham Saxby[4], and he doped up the formula by adding 1.2 grams of **Phenidone** to the **Part A** and doubled the amount of **pyrogallol** in it, (just forget about the sodium metabisulfate which he mentions), which increases the speed of **8E75HD** about three times. That meant cutting exposure times by a third, or to be able to holograph a plate three times the area with the same power laser in the same length of time. The results are identical to the above developer when used with the **'Chrome bleach**. The major drawback of this soup is the more than doubled price of the developer solutions. This developer is not recommended for the high speed films as they all too easily pick up density from spontaneous development fog. It has been used as a developer for pulsed laser holography, and is quite successful for transmission holograms, viz. "The Man on the Motorcycle" or "In the Lab" holograms, but not so good for pulsed single beam reflection. That is best left to the developer tailored for that job, **SM-6**.

BLEACH RECIPE

4 g Potassium Dichromate
4 ml Sulphuric Acid (Concentrated) or 12 g Sodium Bisulfate
One litre Distilled Water

Bleach till clear plus 15 seconds not to exceed two minutes. (An equivalent, pre-mixed concentrate is available as Ilford Holographic Bleach SP679C)

The dichromate not only oxidizes the developed silver, it also donates a chromate ion to form a water soluble silver compound which is washed out, leaving the insoluble silver bromide behind. The exiting salts can oftentimes be observed leaving the holographic plate as a white powder. The plate should be bleached in this bath upside down but not touching the bottom of the tray or hanging vertically in a rack to efficiently remove everything, because salts left behind can accumulate as a scum on

the surface of the emulsion. Water with a lot of minerals can also form a scum with the dichromate, so this bath is best compounded with distilled water. Even the rinses before and after the bleach may contribute enough minerals to form a white powder on the hologram, so a quick rinse in distilled water before and after the bleach will eliminate this noise.

The **'Chrome Bleach** dissolves the exposed and developed silver, so that the holographic pattern is represented by pyrogallol hardened gelatin where the bright fringes had been during exposure, while the dim fringes are represented by untanned gelatin containing silver bromide crystals which had not been disturbed at all by the processing. This is the reverse representation of the fringe system recorded by the classical processing scheme of develop the bright fringe exposed silver bromide grains to elemental silver and then dissolve the unchanged silver bromide grains in the dim fringes with a thiosulfate fixing bath and then change the developed silver where the bright fringes had been back into a clear crystal with a rehalogenating bleach, leaving the dim fringes represented by clear gelatin. Although the two holographic patterns are the inverse of each other, (Which is the positive and which is the negative?) the tonal reproduction in the hologram is just like the original in either case.

This bleach has its roots in the photographic processing scheme used to make black and white slides or movies directly on film stock exposed in a camera. Normally a negative which is tone reversed is the result of developing a camera exposure; but if this negative is bleached away by a dichromate bleach, then the remaining silver halide in the emulsion can be developed into a positive. In photographic terms this is called **"Reversal Processing"**, so this bleach is sometimes called a **reversal bleach**. Developing a holographic plate a second time would only lessen the efficiency, as the darkened silver would absorb the incident light. The silver halide residue remaining after bleaching introduces phase changes to modulate the incoming beam to produce the holographic image and doesn't attenuate the replay beam much.

Because the developed silver is removed from the emulsion, the holographic layer shrinks to a thinner state than its original condition, and the fringe spacing also shrinks proportionately. This means that reflection holograms will replay at wavelengths shorter than that of the exposing laser. More exposed and developed density means a greater shift toward the blue. The range of colors available using this processing trick and a Helium-Neon laser is golden orange to a yellowish green. Tuning in the color is accomplished by trial and error exposure and development tests.

PROCESSING SEQUENCE

DEVELOP*	WASH	BLEACH	WASH	PHOTO-FLO
	2-3 minutes	until clear plus 15"	2-3 minutes	1-2 minutes

***Developing time recommendations:** Two minutes for 8E75HD plates, one minute for film used for reflection holograms; four minutes for film or plates in transmission mode. Any times between one and eight minutes may be used to bail out over or under exposure.

Since Pyrochrome is used as a one-shot developer, the developer can be dumped out with the plate left behind, and the same tray is used for the rinse, where the plate and the tray can be flushed clean with water pressure. After 2-3 minutes, pour in the bleach, which can be re-used, then rinse the plate and tray together again, but use the Photo-Flo only in a tray devoted to that chemical which must be kept the most pristine.

In the summer of 1982 at **Lake Forest College** I tested all the different processing schemes then popular and published. I turned in a report to Dr. Jeong, who published the **Pyrochrome** formula as his recommended processing with the instruction sheets that he sent out with film for his mail-order holography supply business.

In 1983 I brought in PHOTOGRAPHERS' FORMULARY as an advertiser for the now-defunct "advocate of holographic science, art and technology", holosphere. Dr. Jeong asked me if **Pyrochrome** was still my pet process, and before I knew it, Photographers' Forrmulary was carrying the **JD-1 Holographic Film Processing Kit.**

REFERENCES

1. Should be a holosphere article on his Penroses' Triangle.
2. R. L. van Renesse and F. A. J. Bouts, Optik 38, p.156 (1973).
3. R. L. Lamberts and C. N. Kurtz, "Reversal Bleaching for Low Flare Light In Holograms", Applied Optics 10, 1342 (1971)
4. Graham Saxby, "Jottings From the U.K.", holosphere, Volume 12, Number 5. p.9 (1983)

CWC2

CWC2 is the moniker for a developer which was introduced in the March 15th, 1984 issue of Applied Optics[1] in an article by D. J. Cooke and A. A. Ward, hence the **CW** part of the name. Dr. Cooke is one of the authors of **"Volume Holography and Volume Gratings[2]"**, a technical book which lists for about $100. Mr. Ward was a co-author[3] along with Nick Phillips for the first article on using the dreaded **PBQ** as a bleach for reflection holography[4].

When I first read the article, I thought that it was just another paper that promised a lot but would deliver nothing. The original **PBQ** recipe, the infamous **GP432**, never really seemed to work, even though that was the formula published by **Agfa** on their Technical Data Sheets[5]. But since I had invested in a half-pound of **PBQ**, ($22) I figured I had to try it so that maybe I could use up the poison.

I set up my **Standard Single Beam Reflection Test Object**, a silver spray painted waffle iron mold. This object presents a not very deep texture which is homogenous throughout the exposure test quadrants. Plus it's fun to look at the pseudoscopic side because it then looks like the waffle. The holographic plate sits on three ball bearings glued onto the waffle iron, and a piece of cardboard the size of the holographic plate is laid on top of it. The cardboard is a test exposure mask. One of its quadrants had been cut away, so that four different exposures can be made on the plate as the masking card is rotated between them.

In the first round of testing, I compared this new process to the then current champions, the "original recipe **Pyrochrome**[6*]", and the phenidone-doped **"Pyrochrome Plus"** of Graham Saxby[7]. 10 by 10 cm squares were cut from 30 by 40 cm **Agfa 8E75HD** plates, and placed on the test object. Each plate received four exposure doses, approximately 50, 100, 200, 400 microJoules per square centimeter** in each quadrant thanks to the exposure mask. For each developer three of these test plates were shot so that there was a plate developed for one, two or four minutes. The **CWC2** developed plates were bleached in the **CWPBQ2** formula, the **Pyro** developed ones in the **'Chrome** silver solvent bleach.

The **Pyrochrome** processing worked as expected, with a replay color of orange with the weak exposure and a green at the maximum exposure, thanks to the shrinkage of the gelatin and therefore

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*. See the **Handout, PYROCHROME.**

. See the **Handout, EXPOSURE DOSES.

the fringe spacing as more of the exposed and developed silver was removed in the bleaching. But the **CWC2** developed and **CWPBQ2** bleached plates were all the same color; laser red. The hologram looked red under white light, but when illuminated with laser light, the image was also reconstructed so well, that it could steal the light from the object underneath and make a reconstruction that was brighter than the actual object! And even more remarkable, the plate could be repositioned on top of the object and generate real time interferometric fringes! This definitely shows that there is no shrinkage and distortion of the recorded interference structure, which makes this process the highest in recording fidelity.

And the highest in brightest. Even though the holograms are longer wavelength replay compared to the **Pyrochrome**, where our eyes are less sensitive, the image looks "solider". But this process also gives noisier results at the greater exposures - the plate takes on a pale blue milky appearance so that the shadow areas are not completely black. This is due to scatter from the newly rehalogenated grains which grew in size during the bleaching. The noise is dominated by the blue end of the spectrum, and will be obvious under white light illumination, but the same exposure will look less noisy illuminated by red laser light. Putting a red filter on the replay light will also alleviate this condition.

Comparing the plates with different development times showed that as the development time increases so does brightness as well as noise. Two minutes proved to be the best compromise for this batch of plates, and later experimentation with **8E75HD** film used in reflection mode showed that one minute was fine for that application.

Other experiments attempted on that day included a plate developed in **CWC2** but bleached in the **'Chrome** bleach. This yielded a plate with four different colors in each of the quadrants, but the colors were shifted even more to the green than those of the corresponding exposures in the **Pyro** developed plates. For instance, the **Pyrochrome** processed plate may yield a slightly shorter than laser red replay at 50 uJ/cm2 but the **CWC2** and **'Chrome** bleach combo would give a definite orange. The **Pyro** developer tans the gelatin so that it is stronger structurally than the gelatin in an area developed by **CWC2** to the same density, where the shrinkage then is much more severe. Simply by choosing the proper developer-bleach-exposure combination, the holographer can generate any color from the exact laser replay to a color approximately 150 nm shorter.

He-Ne HOLOGRAPHER'S PALETTE

633 nm	**633-550 nm**	**600-500 nm**
CWC2 Developer	Pyro Developer	CWC2 Developer
CWPBQ2 Bleach	'Chrome Bleach	'Chrome Bleach

What about plates developed in **Pyrochrome** developer but bleached in **CWPBQ2**? The plate took a long time to bleach, and did not look very good, as it appears that the wavelength had been shifted to something slightly longer. The heavily tanned gelatin prevented the flow of bleach into the emulsion, and the tanning by the developer had occurred while the emulsion was wet and bloated, so that the fringe system was expanded to Bragg reflect at a longer wavelength than the recording one. This may have applications for holographers starting out with green wavelengths and intending to go to longer replay colors.

What about transmission holograms? Previously I had tested five different developers (Original recipe **Pyrochrome**, **Pyrochrome Plus**, **Kodak D-19**, **D-19 Minus**[8], and **Agfa GP61**[9]) coupled with a reversal bleach and had come to the conclusion that all the developers used were capable of the same results, the only difference being the exposure energies necessary. Setting up my **Standard Transmission Hologram Exposure and Development Setup**, which is a piece of wrinkly glass placed in the path of the diverging light issuing from the spatial filter and used as a transmissive object, placed approximately 15 cm away from and parallel to the holoplate with a large mirror next to it angled so that the light missing the glass is directed to the holoplate as a reference beam* and duplicating as close as possible the previous transmission test's alignment by replaying one of the previously shot test holograms and arranging the equipment to coincide with their positions in the hologram's reconstruction, I shot holograms with an exposure series of 50, 100, 200, 400 uJ/cm2 on **Agfa 8E75HD** four by five sheet film and processed them for 1,2, 4 and 6 minutes development time, a set bleached with **PBQ**, the other with the reversal bleach. The latter looked just like the original set; the new developer worked pretty much like the rest. But the **PBQ** bleached ones were significantly brighter, and the replay reference angle stayed the same as the recording one. Again, overexposed areas looked a bit milky, but the signal to noise ratio was still very high, mainly because the signal was greatly increased. So I adopted this process for my transmission holograms also.

The Optimal Developed Density for both transmission and reflection holograms is about 2.0 to 2.5; pretty dark. It is

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*. See **PROJECT 1b** in the **Handout, SEVEN SINGLE BEAM PROJECTS.**

hard to give an exact number, as reading the density of a hologram is difficult because of surface artifacts. But the density is somewhat irrelevant, as fine tuning for optimal results is more by trial and error exposure bracketing around the best guess. Usually I bracket over and under 200 microJoules/cm2 for **8E75HD** used at 633 nm and the same for **8E56HD** used at 515 nm.

The reason why **PBQ** bleach gives brighter results than the reversal bleach is not because of the ingredients but because of its mode of action. In both processing schemes, the developer changes the crystal clear light-sensitive silver bromide grains which were in the bright fringes into elemental silver filaments, resembling steel wool pads. Nothing happens to the silver bromide grains sitting in the dim fringes. But the reversal bleach is a silver solvent thanks to the potassium dichromate in it, and all the developed silver is dissolved away just like sugar in water. This leaves only the gelatin matrix to represent the bright fringed areas of the holographic pattern, with the dim fringes represented by areas containing the original complement of silver bromide in the emulsion. But the application of a rehalogenating bleach like **CWPBQ2** changes all the developed silver strands back into transparent silver halide grains, silver bromide in particular for this bleach.

Holographic plates start off with a homogenous distribution of silver bromide grains in them, and if all the developed silver were changed back into its original form, the plate should then regain its virgin condition, and there would be no modulation of the incoming reconstructing light since there is nothing to differentiate where a bright fringe had been as opposed to where the dim ones had been. But this process works really well, and the theory is that the developed grains migrate into the dim fringe areas as they are being rehalogenated. Again the bright fringe areas are represented by pure gelatin, and the dim fringe areas contain silver bromide, but there is now more modulable material in those areas so that efficiency is higher. Since nothing left the emulsion, things were only rearranged in there, the original thickness of the layer is preserved along with the spacing of the fringes during recording, so that it is possible to replay a reflection hologram with the laser that made it.

At first I thought that this migration-diffusion mechanism was unreasonable, but it was proven to me when I was making some extremely low frequency gratings*. They had fringe spacing of about 2 line pairs per mm; these fringes are visible to the naked eye. I made my first exposure test, developed and bleached in **CW**

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*. See the **Handout, LOW FREQUENCY DIFFRACTION GRATINGS SET UP.**

 c Ed Wesly

solutions, and discovered almost no diffraction while wet. It dried while I was interrogating it with the undiverged laser beam, and I could see in the woodgrain caused by internal reflection between the two glass surfaces an excellent red Lippmann mirror. The process made a better hologram of the back of the glass than it did of the coarse interference system!

The simple grating had a fringe spacing of 100's of microns; the reflection grating's spacing had fringes about 300 nanometers apart, which is three orders of magnitude difference. If it were true that the silver grains were swimming from bright fringe to dim fringe as they rehalogenated, then this mechanism would be more effective in travelling short distances rather than longer ones.

Develop - rehalogenating processes then have a lower limit of useful spatial frequency, and don't really come into their highest efficiency until about 1000 lines per millimeter, as papers by Hariharan[10] and Ward[11] show. Benton had also predicted these effects when writing about his **IEDT** processing[12], which shifts the unexposed silver grains which had been in the dim fringes over to the developing bright fringe grains. These are extreme cases; certainly the process functions well on fringes formed in the transmission mode by an object placed along the normal to the holographic plate and a reference beam incident at 45 degrees from the normal.

The lack of low spatial frequency response aids in the suppression of intermodulation noise from the object's light interfering with itself. The fringes formed by points on the object are very widely spaced for points immediately next to each other, and are at their minimum for the interference caused by the extreme ends of the object, but rarely are these fringes as tiny as the reference - object fringes. The process will tend to ignore these coarse noise fringes and strengthen the more closely packed holographic ones. Bullseyes caused by dirt on optics will be less apparent on the **CW** processed holograms as the processing makes them lower contrast. Ditto for the dreaded woodgrain. It is strange to think of a holographic material's modulation transfer function being at zero for the low spatial frequencies, then climbing to a peak in the 1000's of line pairs per millimeter then falling off. But silver halide materials processed in this mode are not alone in this respect, as **DuPont's Photopolymers** which work by a diffusion mechanism exhibit this effect, with products manufactured specifically for reflection or transmission work.

THE RECIPE
The developer formula, as first published looked like this:
10 g Catechol
5 g Ascorbic Acid
5 g Sodium Sulfite
50 g Urea
30 g Sodium Carbonate
Water to make one litre
But I changed it to look like this:

CWC2 Part A
20 g Catechol
10 g Ascorbic Acid
10 g Sodium Sulfite
50 g Urea
Water to make one litre

CWC2 Part B
60 g Sodium Carbonate
Water to make one litre

It was broken up into two parts like the **Pyrochrome** type developers to extend the shelf life. Notice that the **Part B** is exactly the same as **Pyrochrome Part B**. The amount of everything is double from the published formula, as you are in essence making two litres of working solution. The urea is not doubled, as I made a mistake in weighing it once and only put half in the soup and it seemed to make no difference in the results.

The Catechol is one of the developing agents in this brew, and contributes the second **C** in the formula's name, which is the second of their formulae that was catechol-based. Like Pyrogallol, it is a tanning developer, although not as strong. It not only develops the exposed silver bromide grains, but tans the gelatin for structural rigidity. Ascorbic Acid is the other developing agent in here, but it does not affect the gelatin the way the Catechol does.

The combination of developers exhibit super-additve effects; more density is formed than would be expected based on the sum of the performances of each of the developers alone. By not totally relying on the tanning Catechol to provide the density, enough silver can be developed to fuel the diffusion bleaching action, with the proper amount of tanning to retain the structural integrity of the gelatin. Without the Ascorbic Acid the results can be disappointing, as noted in the section on **CWC2.5** below.

Sodium Sulfite is included to preserve the developing agents. Ten grams seems to be the proper amount as the two unmixed parts will last for a month on the shelf. Even mixed they will last all day, especially if left in a covered tray. Excessive amounts of sodium sulfite, like 90 g/l as found in **Kodak D-19**, can dissolve the silver bromide grains, causing unwanted

shrinkage of the emulsion from the developer. It also prevents the tanning developer, catechol, from staining the gelatin. **CWC2** leaves a light beige color, if any, in the hologram.

Urea is an unusual ingredient to find in any developer. Its role is to soften the gelatin to aid the penetration of the bulky molecular chain of the organic developers. This makes development more even throughout the depth of the emulsion. Thanks to this additive, I was able to develop some of the infamously overhard **Agfa** plates[13] that were a disaster developed in **Pyrochrome**. This batch of plates seemed to require much more than usual exposures to get any density, but in truth it was not a matter of sensitivity but of lack of developer penetration through the depth of the emulsion which was responsible for the slow rate of darkening. More exposure developed more grains at the top of the gelatin because the tanning action of the **Pyro** sealed off diffusion of developer downward while the bottom grains were still thirsty, so the density got in the proper range but it was all confined to the upper level, so the holograms were weak no matter how you applied the Pyro. But the **CWC2** opens up the pores and evenly develops the whole volume of the coating.

Sodium Carbonate provides the proper pH environment for the developing agents to do their thing. It doesn't seem to matter if anhydrous or monohydrated Sodium Carbonate is used.

Time of development varies with the application. For reflection work, I use one minute for **8E75HD** film, two minutes for plates, although you may want to test this for yourself. For transmission holograms, I usually use 2 to 4 minutes on most materials, and have gone as long as eight minutes when trying to bail out an underexposed mess.

The original paper kept the brew at **20C (68F)**. Here at **SAIC** our recommended temperature is **75F** to speed things up a bit. Shorter exposures will produce the same density if the developer is at a slightly higher temperature. Using this higher temperature makes the holographer more aware of checking it. If the developer temperature drops 4-5 degrees from 75F, the time can be extended. But dropping under 65F can be disastrous, as almost all silver-halide developers for photographic as well as holographic purposes lose their power, and don't develop any appreciable density.

A variation of **CWC2** was published[14] omitting the ascorbic acid and the urea which I christened **CWC2.5**. I believe that the error was a typographical one, as the missing ingredients would have fit on a single line. I tried it, figuring if the omission of the ascorbic acid and urea gave just as good a result, I could save money by not using them. But all I got were not very bright

holograms with a dark tan stain, similar to the Pyrochrome tan. But the paper on holographic reciprocity law failure by Kostuk et al.[15] lists the shortened formula as their main developer and quotes efficiencies of 50%, which is totally erroneous. This leads me to believe that the results documented in this paper are entirely bogus, as well as those in a related paper from this same Stanford group[16].

The **CWPBQ2*** **Bleach** formula is as follows:

15 g Citric Acid
50 g Potassium Bromide
Water to make one litre
Add 2 g p-Benzoquinone per litre of bleach just before use.

At one time I had broken the bleach into two solutions, one an acidified salt solution, the other 4g/1 PBQ, but inevitably the PBQ oxidized into uselessness within a day and was wasted. The citric acid/potassium bromide solution will last indefinitely, just pour out what you need and then weigh out and add the proper amount of **PBQ** for that volume.

The Citric Acid serves two purposes: to provide a buffered acid environment for the oxidizer, **PBQ** to work in, and also minimizes the stain of the **PBQ**. Comparing holograms bleached with this **PBQ** formula with those bleached in **GP432**, a **PBQ**-based bleach with boric acid as the buffer shows that the **PBQ** in the latter stains the gelatin. Old-time photographers knew the value of citric acid as a tanning stain remover by prescribing the raw crystals to be rubbed over the fingers to remove pyrogallol stains.

The Potassium Bromide is the salt, which donates its bromine to the developed black silver to change it back to a transparent crystal, silver bromide. Fifty grams is a good compromise for signal to noise; 100 grams bromide in the bleach gives brighter but noisier results, while 25 grams gives less noise at the expense of efficiency[17].

PBQ is the oxidizing agent used in this bleach. It knocks electrons out of the silver atoms so that it becomes an anion, which is positively charged since there is one less electron than protons in the atom. The bromine in the bleach solution picks up the electron, becoming a negatively charged cation, and then the two ions form a crystal by ionic bonding. The positive silver ions are locked in a lattice by their attraction to the bromine

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*. For Cooke-Ward Para-BenzoQuinone Number 2. They called the previously published **GP432** **PBQ**-based formula **PBQ1** in their artical.

which is negatively charged in the newly-formed silver bromide crystal lattice.

PBQ is the oxidized remains of the developing agent hydroquinone. It is quite poetic that an alkali solution of hydroquinone will develop the transparent silver bromide grains into black silver while an acid solution of **PBQ** will bleach the black developed silver back into a transparent crystal.

The relationship between developers and oxiding agents was utilized in a series of bleaches formulated by Nick Phillips and Hans Bjelkhagen[18]. A variety of bleaches were compounded using developing agents which were then turned into oxidizing agents by an even stronger oxidizer, potassium persulfate.*

Efficacy of this organic compound is quite high. Just two grams of **PBQ** per liter will clear a plate in the same time as 30 grams of Ferric-Sodium EDTA or Potassium Ferricyanide, or 35 grams of Copper Sulfate. A few drops of the solution on my bathroom/darkroom carpet bleached the fibers perfectly white.

But it is a very smelly, toxic compound that causes distress to the eyes, nose and lungs. There are a couple of "cures" for **PBQ**, which seem to work just as well as the **CWPBQ2** recipe. The first one, described by Nick Phillips in holosphere[19], is based on **Ferric EDTA****:

30 g Ferric Sulfate (not Ferrous!)
30 g di-Sodium EDTA
30 g Potassium Bromide
10 ml Sulfuric Acid (concentrated) or 30 g Sodium Bisulfate
One liter of Water

Or if you have a source for Ferric EDTA without having to mix two chemicals together***:

30 g Ferric Sodium-EDTA
30 g Potassium Bromide
10 ml Sulfuric Acid (concentrated) or 30 g Sodium Bisulfate
One liter of Water

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*. See the **Handout, THE PBU SERIES.**

****Ethylene Diamine Tetra-Acetic Acid**

*****Ironically it is cheaper to buy the two separate chemicals and make the Ferric EDTA in solution. It has something to do with **OSHA** regulations at the chemical factory.

Ferric EDTA is the oxidizing agent in this case, and the acid environment is supplied by sulfuric acid, with pH around 6.0. Ten ml of the concentrated form of Sulfuric Acid could be used to provide the proper pH, or 20 ml of the usual concentration of 48%, (which is cheaper to ship, and is more commonly known as battery acid) could be used, or Sodium Bisulfate, a cheap powder that forms sulfuric acid when it is dissolved in water might be more to your liking. The conversion factor is 2.82 grams of the powder for each ml of concentrated acid, which can safely be rounded to 3 g/ml. KBr plays its usual role as the source of bromine.

Although this bleach gives results as bright as those with the **PBQ** and is more environmentally safe, (color photographic processors use Fe EDTA for their kiloliters of bleach as it is safe to release into the sewer) the color always seemed to shrink to a shorter wavelength. This fact coupled with the cost of Fe EDTA (>$200/lb.!) leads me to use another rehalogenating - diffusing formula, the Copper Sulfate bleach described by Jeff Blyth in the now defunct **Wavefront** magazine[20]:

35 g Copper Sulfate
10 ml Glacial Acetic Acid
110 g Potassium Bromide
One liter of Water

Copper Sulfate is the driving force in this bleach, while a different organic acid is used to buffer the pH, running at 5.7. This bleach seems to be exactly equivalent to **CWPBQ2**, plus it has a beautiful cyan color when fresh. As it goes bad, it turns a sickly green.

A very interesting property of all the above bleaches is that they can erase a latent image! I made this discovery by accident when I placed a plate in the **Ferric EDTA bleach** before developing[21]. I rinsed the plate off, thinking that it had only gotten wet, then tried to develop it, and no density would appear even after ten minutes in **CWC2**. The bleach had replaced the missing bromine of the developable speck on the silver bromide crystal. If the lights are ever turned on while the plate box is open, the plates can be salvaged by a dunk in any of these rehalogenating/diffusing bleaches, a 3 to 5 minute wash, Photo-Flo solution for 1 to 2 minutes, and an air dry, **ALL IN THE DARK!**

PROCESSING REGIMEN:
DEVELOP one to six minutes. (Two minutes is a good starting point.)

WASH two to three minutes in running water.

BLEACH for one and a half times the clearing time.
WASH three to five minutes. (The sensitizing dye undergoes an indicator reaction, turning pink in the acid bleaches, and back to normal as it returns to neutral pH.)

WETTING AGENT one to two minutes.

DRY.

The **CWC2** developer with rehalogenating bleach is my primary choice for **Agfa 8E75HD** and **8E56HD** materials for transmission masters and transfers, and for reflection holograms that replay in the laser color. For shorter than laser color replay I would change the bleach to a solvent one, or go to the **Pyrochrome** system.

This process works on **Agfa 10E75** materials, but is quite a bit noisy, especially compared to the wonders that original formula **Pyrochrome** works on this material.

For **Bulgarian Academy of Sciences HP-490** plates this formula is my only choice, as I do not have their colloidal developer formulae. The final result is a crystal clear plate with good efficiency in the reflection mode with laser color replay.

This process can be applied to the **Ilford products**, but because this manufacturer includes a **Built-In Pre-Swell** (**BIPS**) ingredient, the final color of reflection holograms will shift to shorter wavelengths. To preserve the wavelength I use their **Pyrogallol-based developer** with one of the above rehalogenating bleaches.

For **Kodak** products, this process doesn't work so well because of their extra hard gelatin makes diffusion very difficult to accomplish.

In the Fall of 1987, Dr. Tung Jeong asked me if I knew any holographic developers which lasted longer than the **Pyrochrome** one. I told him **CWC2**, and I remembered how he had marketed the **Pyrochrome** process through Photographer's Formulary a few years ago as the **JD-1 Hologram Processing Kit**. Sure enough, in the next mailing I received from the folks in Montana[22] there was the **JD-2 Hologram Processing Kit**, which included the **CWC2** developer, designed to be mixed in **A & B** solutions, as described in this

handout, and with the **'Chrome** bleach. Of course this silver-solvent bleach does not give the strong exact laser wavelength replay that is possible with the developer but greenward-shifted reflection hologram replay. If he had realized that the **'Chrome** bleach could be turned into a rehalogenating bleach by adding a salt solution to it[23], then the kit could be have been so versatile that it could answer all needs.

During my last months working full-time at the Lake Forest College Center for Photonics Studies, Dr. Jeong was querying me about dry substitutes for Acetic Acid. He had confided in me that he would like to update the **JD-2** kit with a rehalogenating bleach, as the typically green holograms the kit gave were not so exciting. He knew that I was using the **Jeff Blyth Copper Sulfate Bleach** at the School of the Art Institute of Chicago, since it seemed to be more environmentally palatable than **PBQ** and cheaper than **Ferric EDTA**. But the Acetic Acid liquid, in no matter how small an amount, carried a hefty shipping surcharge. Although I knew that Sodium Diacetate dissolved in water produces Acetic Acid[24], (much like Sodium Bisulfate produces Sulfuric Acid in solution) I pleaded ignorance, as I could see more money coming his way and none for me.

In the Summer of 1993, while I was working with Nick Phillips in the labs at Lake Forest College, we were processing holograms with the **Copper Sulfate Bleach**. Dr. Phillips was astounded with the high (110 g/l) concentration of KBr in this formula. He recommended diluting the bleach with an equal part of water, and it worked just as well for his current experiment. Dr. Jeong was quite excited by this revelation, as now his new and improved **JD-3** Kit could include a rehalogenating bleach that would cost half as much as he had projected, leaving more room for profit.

The acid substitute that he arrived upon was Succinic Acid, a powder which doesn't demand a handling surcharge. However this bleach formulation (18 g CuSO4, 2 g Succinic Acid, 55 g KBr) takes a long time to bleach, since the pH is higher, and seems less noisy but at the expense of brightness. If Dr. Jeong had indulged in further experimentation he probably could have hit upon a more satisfying formula. Purchasers of the **JD-3** kit would serve themselves well by replacing the Succinic with Acetic, easily purchased at camera stores, and mixing up the bleach formula with half the amount of water.

This process has remained my standard for so long because it fully utilizes the potential of the material. Side by side comparisons with the likes of **D-19**, **Holodev 602**, etc. show that others can give similar or equivalent results, yet never surpassing the **CWC2** performance, as they are pushing the limits of the material. The next big breakthrough in brighter silver

halide holograms will have to come from improvements in the films themselves.

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noisier.

24. 2.3 grams of Sodium Diacetate added to water yields the same pH as adding 1 milliliter of Glacial Acetic Acid; use .66 gram of Sodium Diacetate for every milliliter of 28% Acetic Acid solution. From 150 Do-It-Yourself black and White Popular Photographic Formulas, Edited by Patrick D. Dignan, Dignan Photographic, North Hollywood, California, 91606. Available from Photographer's Formulary.

A Toast to Nick Phillips

Ed Wesly

ABSTRACT

The art of holography requires bright holograms with good signal-to-noise ratios. The author profiles a man who pioneered techniques in silver-halide holographic material processing to make reflection holograms that are eminently viewable.

Silver-halide–based photographic materials were used to record the first holograms made by Gabor, Denisyuk, Leith and Upatnieks. These materials will probably remain useful in holography forever, due to their high sensitivity at all parts of the visible spectrum, in comparison to other available materials, which lag an order of magnitude or two behind in photon catching. Because of this, these silver-halide–based materials will continue to be the medium of choice for self-supporting holographic artists using small lasers.

In the beginning, holographic processing followed basic photographic darkroom conventions: develop, stop, fix, wash, add wetting agent, dry. But this procedure did not produce bright holograms, especially the reflection type, since the blackened, developed silver absorbed much more of the light than it diffracted. Bleaching techniques were suggested by Cathey in 1965 [1], and this resulted in a plethora of papers, many peddling not just the proverbial snake oil but also the use of toxic ferricyanides and mercuric chlorides.

A paper that remains a classic to this day is "An Advance in the Processing of Holograms", by N. J. Phillips and D. Porter [2]. They introduced the use of a concentrated photographic developer, Neofin Blue™, as a developer for pulsed holography. Neofin Blue™ is not only expensive but hard to obtain, so its use has been superseded by special formulations (such as my SM-6 [3]). More importantly, this paper introduced a relatively benign oxidizing agent, ferric nitrate, in a bleach used after fixing to rehalogenate the developed silver in the bright fringe areas of the holographic pattern into silver bromide (Formula 1). This bleach was gentle to the gelatin, avoiding the formation of noise due to surface relief, and it was observed that ferric nitrate also had hypo-clearing-agent capabilities. It also incorporated a desensitizing agent, phenosafranine, to eliminate printout, while also inhibiting grain growth to noisy levels. The ferric nitrate formula seems to still be the favorite bleach of white-light transmission holographers [4], such as Hans Bjelkhagen of Holicon, who prefers this over the simpler GP 431 formulation (Formula 2) for pulsed masters developed in Neofin Blue™ diluted 1:1.

Formula 1. Original Ferric Nitrate Formula

20 g	Glycerol
500 ml	Deionized Water
500 ml	Isopropyl Alcohol
300 mg	Phenosafranine
150 g	Ferric Nitrate
33 g	Potassium Bromide
1 liter	Water

Dilute 1 to 4 with water before use.
Bleaching time: One and a half times the time it takes to clear.
Temperature: 20° C
Agitation: Intermittent
For rehalogenation after fixing. This stock solution lasts indefinitely; working solution, about 1 week [23].

Phillips's next significant paper, "Advances in Holographic Bleaches" [5], introduced a new concept of bleaching to coincide with the introduction of Agfa's new line of improved Holotest™ emulsions [6] (Formula 2 and Formula 3). By rehalogenating the oxidized silver directly after development and skipping the fixing step, dramatic increases in brightness could be achieved. What is most remarkable about this process, and a tribute to Phillips's genius, is that conventional photographic wisdom would dictate that this type of system should not work!

Holographic plates initially contain a homogenous distribution of silver-bromide grains, and if all the developed silver were changed back into its original form, the plate would regain its virgin condition. In this condition, there would be no modulation of the incoming reconstructing light, since there would be nothing to differentiate where a bright fringe had been and where the dim ones had been. In reality, this process works really well, and the theory is that the developed grains migrate into the dim fringe areas as they are being rehalogenated. The bright fringe areas are represented by pure gelatin, and the dim fringe areas contain silver bromide, but the increase in modulable material in those areas increases efficiency. Since nothing leaves the emulsion—its elements are merely rearranged—the original thickness of the emulsion layer is preserved along with the spacing of the fringes during recording, so that it is possible not only to replay a reflection hologram with the laser that made it but to replace the hologram onto the object and generate real-time interferometric fringes with it.

At first I doubted that this migration-diffusion mechanism would work, but its effectiveness was proven to me when I was making some extremely low frequency gratings.

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Formula 2. GP 431

150 g Ferric Nitrate (9-Hydrate)
30 g Potassium Bromide
0.3 g Phenosafranine (optional)
1 liter Water

Dilute 1 to 4 with water before use.
Bleaching time: One and a half times the time it takes to clear.
Temperature: 20° C
Agitation: Intermittent
The most enduring of the classic bleaches. The phenosafranine may need to be dissolved in an alcohol or in a bit of very hot water before being added to the stock solution.
This stock solution lasts indefinitely; working solution, about 1 week [24].

They had fringe spacing of about two line pairs per mm; these fringes are visible to the naked eye. I made my first exposure test, developed and bleached without fixing, and discovered almost no diffraction while the hologram was wet. It dried while I was 'interrogating' it with the undiverged laser beam, and I could see in the 'wood grain' caused by internal reflection between the two glass surfaces an excellent red Lippmann mirror. The process made a better hologram of the back of the glass than it did of the coarse interference system.

The simple grating had a fringe spacing of hundreds of microns. The reflection grating's spacing had fringes about 300 nm apart—half a wavelength of red light, or one-thousandth of the original size. If it were true that the silver grains were swimming from bright fringe to dim fringe as they rehalogenated, then this mechanism would be more effective in travelling short rather than long distances.

Developing-rehalogenating processes then have a lower limit of useful spatial frequency and do not reach their highest level of efficiency until about 1,000 lines per mm, as papers by Hariharan [7] and Ward [8] show. Benton had also predicted these effects when writing about his Intra-Emulsion Diffusion-Transfer (IEDT) processing [9], which shifts the unexposed silver grains that had been in the dim fringes over to the developing bright-fringe grains. But gratings with fringes so large that they are visible to the eye are extreme cases; certainly the process functions well on the size of fringes formed in the transmission mode by an object placed along the normal to the plate and a reference at 45° from the normal.

The lack of low spatial-frequency response aids in the suppression of intermodulation noise from the object's light interfering with itself. The fringes formed by points on the object are very widely spaced for points immediately next to each other, and are at their minimum for the interference caused by the extreme ends of the object, but rarely are these fringes as tiny as the reference-object fringes. The process tends to ignore these coarse noise fringes and to strengthen the more closely packed holographic ones. Bull's-eyes caused by dirt on the optics become less apparent on the developed-rehalogenated holograms, because the processing lowers their contrast. The same is true for the dreaded wood grain. It is strange to think of a holographic material's modulation-transfer function being at zero for the low spatial frequencies, then climbing to a peak in the thousands of line pairs per mm, and finally falling off. But silver-halide materials processed in this mode are not unique in this respect. Du Pont's OmniDex® family of photopolymers, which work by a diffusion mechanism, also exhibit this effect when used with products manufactured specifically for reflection or transmission work.

It is critical that the rehalogenation be performed in aqueous solutions in order for the diffusion of the silver to take place. If the developed holographic plate is rehalogenated by bromine vapor à la Thiry [10] or Graube [11], there can be no 'swimming' of silver bromide from one area to the other, which is necessary for the plate to return to its original consistency.

This subtle phenomenon can only occur with extremely fine-grained holographic or Lippmann-type emulsions. To illustrate how subtle Phillips's method is, not one of the researchers in Lippmann photography at the turn of the century, including some of the greatest minds in photographic research, ever attempted the simple experiment of rehalogenation in aqueous solutions. If they had, they could have solved one of the basic processing problems of Lippmann photography, that of retaining emulsion thickness to preserve color veracity. Most Lippmann photographers either developed to colloidal silver or developed, fixed and bleached in mercuric chloride and used some plumping agent in the emulsion to bring it back to its original thickness. Phillips's scheme rearranges all the modulable material in the layer, without losing any, so there is no shrinkage of the fringes to shorter wavelengths. It will be interesting to see if there will be any renewal of Lippmann experiments—

Formula 3. GP 432

50 g Potassium Bromide
1.5 g Beric Acid
2 g p-Benzoquinone (PBQ)
(add just before use)
1 liter Water

Dilute 1 to 4 with water before use.
Bleaching time: One and a half times the time it takes to clear.
Temperature: 20° C
Agitation: Intermittent [25]

other than those of Phillips himself—using these new processing techniques [12,13].

The proof of the processing is in the holograms. Holograms processed using Phillips's method helped account for the success of the Light Fantastic gallery exhibitions in the late 1970s, which acquainted the general public with images that were extremely realistic, thanks to the high brightness and the black shadows made possible by the low signal-to-noise ratio. The second bleach mentioned in "Advances in Holographic Bleaches" [14] was adopted by John Kaufman [15], the dean of triethanolamine color control, in combination with the developer Kodak D-19, as his basic process. If not using Phillips's recipes verbatim, most workers have adopted his development-rehalogenation scheme.

The eradication of the fixing step also eliminated the characteristic odor of 'hypo' (thiosulfates), which has been the bane of photographic darkrooms since the days of Daguerre. It is an unpleasant smell for most people, and some are allergic to it. It is also unhealthy for bleached holograms, since it is a solvent for silver halides, which comprise the modulation ingredient in the holographic layer. Even the airborne particles that account for the smell are capable of ruining holograms.

Phillips has been criticized by the safety-conscious for having introduced an even nastier-smelling chemical, p-benzoquinone (PBQ) (Formula 3 and Formula 4), into which the developing agent hydroquinone oxidizes as it gets

Formula 4. PBQ #2

30 g Potassium Bromide
15 g Borax
2 g Potassium Dichromate
2 g p-Benzoquinone (PBQ)
(add just before use)
1 liter Water

Bleaching time: One and a half times the time it takes to clear.
Temperature: 20° C
Agitation: Intermittent [26]

Formula 5. 'Benign' Ferric EDTA

ORIGINAL
30 g Ferric Sulfate
30 g di-Sodium EDTA
30 g Potassium Bromide
10 ml Sulfuric Acid (concentrated)
1 liter Water

REVISED
30 g Ferric Sodium-EDTA
30 g Potassium Bromide
30 g Sodium Bisulfate
1 liter Water

Bleaching time: One and a half times the time it takes to clear.
Temperature: 20° C
Agitation: Intermittent
Less hazardous to work with than PBQ. Either version of the recipe gives the same result; the choice depends on the availability of ingredients. Leaving the solution exposed to air (uncovered tray) will extend the lifetime of the oxidizer [27].

Formula 6. Nick's #5

PART A
60 g Sodium Sulfite
20 g Catechol
10 g Hydroquinone
10 g Potassium Bromide
1 liter Water

PART B
20 g Sodium Metaborate
120 g Sodium Carbonate
1 liter Water

Mix equal parts of A and B together before use.
Development time: 4–5 min
Temperature: 23° C ±1° C
Agitation: Constant
Primary recommendation for transmission holograms on Ilford green-sensitive materials, followed by a rehalogenating-diffusing bleach. Properly exposed plates will not show signs of development for 30 sec.

Part A lasts up to a month in a tightly stoppered bottle; Part B lasts indefinitely. The combined solutions last up to a day in a covered tray [28].

Formula 7. Nick's #6

PART A
10 g Pyrogallol
10 g Potassium Bromide
1 liter Water

PART B
20 g Sodium Metaborate
120 g Sodium Carbonate
1 liter Water

Developing time: 5 min
Temperature: 23° C ±1° C
Agitation: Constant
Primary recommendation for Ilford green-sensitive materials for same wavelength replay in the reflection mode when followed by a rehalogenating bleach. Ilford SP737T film and plates will work in this formula but at a loss of a stop in speed. A properly exposed plate will sit in this formula for 30 sec before any darkening appears.

Tray life of the combined solutions is about 15 min. Part A lasts 2 to 3 days in a full stoppered bottle, but Part B lasts indefinitely [29].

spent in the process of reducing silver-bromide crystals into elemental silver. It is certainly a problematic powder to mix. Its very fine dust inflames the sinuses and dries out the eyes. Certainly, personal air masks with organic filters help, and some workers have made spare shower stalls into fume hoods to control the hazard [16]. PBQ takes a very long time to dissolve, and the bleach has a covered tray life of a few hours. It cannot be left uncovered, as this causes it to oxidize into uselessness even more quickly. More importantly, even the solution reeks. Because of these drawbacks, Phillips formulated a rehalogenation/diffusion bleach based around ferric Ethylene Diamine Tetra-Acetic acid (EDTA) as the oxidizing agent (Formula 5). Ferric EDTA is the oxidizing agent commonly used in color photographic processes because it is ecologically benign [17].

When Ilford introduced a new blue-green–sensitive silver-halide holographic recording material in 1988, Phillips eliminated its problem of splash marks (Formula 6 and Formula 7) [18]. The plates were developing splotchily because the solution did not penetrate the entire coating evenly and simultaneously, and the developer darkened some areas more than others. By using a restrainer in the developer to delay developing activity for about 30 sec after immersion (until the light-sensitive coating was totally saturated with developer), much more even development was achieved.

Phillips's next processing publication [19] fine-tuned the ferric EDTA formula with a 'No Patchy Haze' version of this bleach, which cuts down local variations in surface scatter (Formula 8). But the paper "Bridging the Gap between Soviet and Western Holography", which he delivered in Budapest, Hungary, for the celebration of the 90th birthday of Dennis Gabor, introduced the greatest improvement in the processing of holographic materials since the invention of PBQ [20].

After having been impressed by the high signal-to-noise ratio of Russian colloidally developed silver-halide materials in 1979, Phillips tried processing Agfa Holotest™ materials in Russian-style developers. These solutions reduce the exposed silver-halide crystals into red silver, which gets its color from its small, compact grains. Black silver, which is the typical product of development, is composed of long, filamentary strands. The colloidal type of developer works very well with the Russian-style materials with their extremely tiny grains, which are about a third of the diameter of those in Agfa plates. Since scatter is proportional to the fourth power of diameter, Russian plates have less than 1% of the scatter of Western ones. Because of these small grains, Russian plates look as clear as glass, since they do not have the large scattering sites that give a soft, ground-glass look to the Western plates. There is less haze in recording and in replay, contributing to blacker shadows, which add significantly to the apparent solidity of the holographed object. However, since sensitivity is proportional to the third power of diameter, Russian materials need almost 100 times the exposure of Western plates.

When the Agfa plates did not respond well to the single-step colloidal developers, and because he was getting such high efficiency with black-silver development followed by rehalogenating bleaches, Phillips changed the rehalogenated silver bromide into colloidal silver, using a highly diluted developer. In this process, the plate is exposed to light to the saturation point but not enough to cause solarization or to the point of printing out. It is then immersed in the weak developer formula without any agitation. The weak developer breaks down the large, highly scattering silver bromide into little rocks of colloidal silver. This creates an appreciable increase in signal-to-noise ratio, so much so that the true-color holograms that I made with red 633 nm, green 515 nm and blue 476 nm on a single Agfa Holotest™ 8E75HD [21] would not have worked at all if not for this trick. The blue image would have been buried in the blue scatter noise of the Agfa emulsion.

The original colloidal developing formula, which I had dubbed in the beginning 'Reddeveloper', a pun on red developer and redeveloper, and which I now call the 'Blood Bath' because of the characteristic dried-blood color of the finished plate, had six ingredients (Formula 9). But in a slightly

Formula 8. 'No Patchy Haze'

12 g Ferric Sulfat
12 g di-Sodium EDTA
30 g Potassium Bromide
50 g Sodium Bisulfate
1 liter Water

Bleaching time: The time it takes to clear plus 1 min (the total bleaching time is usually in excess of 6 min).
Temperature: 20° C
Agitation: None
A slow, diluted Ferric EDTA bleach that eliminates nonuniform scattering patches throughout the emulsion. The key to success is to avoid the urge to agitate, as this process can take up to 15 min to clear a well-exposed plate [30].

Formula 9. Reddeveloper #1

10 g Sodium Sulfite (anhydrous)
5 g Hydroquinone
10 g Ascorbic Acid
23 g Potassium Phosphate (mono)
30 g Sodium Carbonate
1 liter Distilled Water

Dilute 1 part developer to 40 parts distilled water, otherwise there will be patchiness in the final hologram.
Re-expose plate to ultraviolet or visible light and develop for 5 min with the lights on [31].

Formula 10. Reddeveloper #2

10 g Ascorbic Acid
1 liter Distilled Water

Re-expose plate to ultraviolet or visible light and develop for 4 min with the lights on [32].

later version of the formula Phillips had introduced in his paper "Bridging the Gap between Soviet and Western Holography" [22], he simplified the step to a simple 1% solution of ascorbic acid (Formula 10). This is quite remarkable, as there is no alkali to provide the proper pH to activate the developing agent, and the bath runs at a pH of about 3. Again, this goes against the grain of conventional wisdom.

Not only does this increase the signal-to-noise ratio of the Agfa and Ilford plates to a level comparable to that of Russian-style materials, it also prevents printout. Colloidal silver is fully oxidized, like the black silver in conventional black-and-white photographic negatives and prints, and will not change on its own, as an unstable silver halide will. Holographers looking for that 'hologram-as-a-crystal-clear-window' effect might be daunted by the red color of the emulsion, which unfortunately filters out a bit of the blue and green end of the spectrum. Then again, they may take comfort in the fact that the hologram will be archival and will not change its color over time.

Currently Phillips and Bjelkhagen are researching new formulations of bleaches that create PBQ in the solution by oxidizing hydroquinone with potassium persulfate. PBQ as an oxidizer has advantages over the others, especially regarding efficacy: 2 grams per liter of PBQ does the same job in the same amount of time as 30 grams of ferric EDTA, ferric nitrate, potassium ferricyanide, mercuric chloride or copper sulfate. It also tans, or hardens, the gelatin, preventing the shrinkage that often occurs with the other oxidizers, especially ferric EDTA. Their formula, which they have dubbed Phillips-Bjelkhagen Ultimate (PBU), does not require the nasty ordeal of dealing with powder PBQ, yet it works identically.

I propose a toast to Nick Phillips, the gentleman who has done the most in inspiring us all in the creation of high-quality reflection holograms, and who has thrown off the bondage of his 'commercial ties' to holographic business to give us the knowledge to get the best possible results from holographic materials, so that the medium can progress.

Who knows what may follow—a special monobath, with a developing agent that changes the silver bromide into black silver but whose spent by-product oxidizes the developed silver so that it can be rehalogenated and diffused back to a silver-bromide phase hologram and in which the by-product of the oxidizer then becomes a weak developing agent that changes the silver bromide into a colloidal silver? That would be nice. But if that does not happen, surely the legacy of Phillips will include the perfection of the processing of holograms.

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24. For the source of Formula 2, see Phillips et al. [5]; and Agfa-Gevaert Technical Information Bulletin 21.7271(480).

25. For the source of Formula 3, see [24].

26. For the source of Formula 4, see Phillips et al. [5] p. 120.

27. For the source of Formula 5, see Phillips [17] p. 21.

28. For the source of Formula 6, see Phillips [18] p. 35.

29. For the source of Formula 7, see Phillips [18] p. 35.

30. For the source of Formula 8, see Phillips [19].

31. For the source of Formula 9, see Phillips [20].

32. For the source of Formula 10, see Phillips [22].

RECYCLING OF HOLOGRAPHIC PLATES

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ABSTRACT

This paper reports on what to do with unsuccessful holographic plates--as the glass recyclers are more interested in bottles than plates of glass.

I. FERRIC MAGIC

Suppose you've been overextending yourself for the last 18 hours working on the ultimate master and you've checked the Beam Balance Ratio for the last time and then you make the exposure, only to realize that you haven't restored the object light! The plate is fogged!

Don't shatter the plate into glass shards to slit your wrists; the fog to which you've just exposed your plate can be erased! I discovered this phenomenon by accident; while processing some 4x5 inch plates, I inadvertently immersed them in a Ferric EDTA bleach before the developer. Even after 15 minutes, in CWC2 developer, there was no developed density. (See Table I for formulae.)

Could the bleach have erased the latent image? Current theory on the process of exposure states that a small developable speck of silver is formed on the silver halide grain as the bromine is shooed away by the action of light. The Fe EDTA bleach, being of the rehalogenating family, replaces the lost bromine and restores the grain to its virgin condition. Even the ancient Daguerreotypists realized a fogged plate could be revived with a quick trip back to the Bromine box.

To test this hypothesis, I exposed a piece of 8E75HD film to room light, cut it in half, then bleached one part, and developed both together. There was no density on the bleached part. I next made a photogram on another piece of film by laying some coins on it, then cut it in half, bleached one segment and made a second coin photogram on it. The first exposure did not seem to bother the second.

Would this effect work for holographic exposures? An Agfa 8E75HD plate was fogged by room light, a sliver was cut off, and the remainder bleach-erased and given the same exposure dose and development as a normal plate. The reconstruction of both holograms were identical, yet the unerased sliver displayed density > 4 with the same development!

Sensitometric measurements of virgin plates are compared to Fe EDTA and PBQ erased plates in Table II. Although untreated and Fe EDTA plates are almost identical, it seems that PBQ gives a bit more speed. This may be anamolous, but then again holograms have been recorded in PBQ sensitized layers. (1)

A simple Ferric Nitrate bleach (Table I) was also tested for erasing effects, but this formula did not work, leaving the plate milky and useless. Another unsuccessful experiment was trying to erase a uniformly fogged and developed plate. To re-use the plate the mistake must be discovered and erased before development.

So, if you make a bonehead mistake in the dark, or your pulsed laser doesn't deliver a big enough pulse, or somebody walks into the lab and throws on the light, the plate is not ruined but salvageable.

The only difficulty is cosmetic, and lies in how well the plate is handled. A thorough wash (3-5 minutes) after a couple of minutes in the eraser, I mean bleach, followed by 1-2 minutes in Photo-Flo® and air-dried (all in the dark!) can bring the plate back to its original out of the box condition. If there are streaks, etc., the plate can still be used for feasibility studies.

II. SECOND CHANCE

Another use for fogged plates, implemented before the miraculous discovery above, was to fix out their silver halides and to dichromate the remaining gelatin layer. Starting with plates like this makes gaining DCG experience a snap since the coating variable is eliminated. Everyone is familar to some degree with this technique for Kodak plates either from experience or the literature, but papers dealing with Agfa derived layers are few and far between. I used the pre-exposure procedure outlined by Oliva, et al. (Table III)

Their fixing bath is simply 10% sodium thiosulfate; no hardening agents. The Agfa red sensitizing dye is removed in the methanol baths. Use your masks! Compatibility of that dye with Ammonium Dichromate remains to be tested. Their last bath is a soak in very hot water at 90°C, but accidentally boiling the plates didn't seem to make any difference.

I tried different concentrations of the sensitizer, Ammonium Dichromate, from 2% to 20%, and 5% worked just fine. Exposure to 488 nm light was in the tens of milli-Joules/centimeters squared.

At first the holograms were processed according to Steve McGrew's guidelines in Table IV. But the same results were obtained with only 30" to 1' immersions in the four baths in Table IV at room temperature.

Denisyuk style holograms of coins (what else?) and a small plane mirror to check replay bandwidth were recorded. The replay color was very close to that of the laser's, so good that real time fringes could be observed when the plate was replaced on top the coins which were glued to an Abramson type plate holder.(2) Wavelength upshifting could be coaxed out of the plates, but not the broadband effects (and noise) of the thick commercial pendant gelatins. But the efficiency is not as high as the latter since the gelatin coating after fixing is probably no more than 4 or 5 microns thick.

This process may be of interest to holographers in need of masters for transferring to photo-resist, as it is low-noise and wavelength preserving, with probably more sensitivity at the deeper blue end of the spectrum. Masters and transfers can then be made at the same wavelength in low scatter materials.

The really amazing thing about this process is that previously processed holograms and non-holograms can be put to use thanks to this process! I tried it with a mongrel assortment of plates, all of them first bleached in the above-mentioned Fe EDTA bleach to rehalogenate anything in the emulsion so that it can then be fixed out following the procedure in Table III. Pyrochrome processed plates were treated in the Stain Remover S-13 A and B baths (Table I) prior to that to remove the tan stain and soften the gelatin. Results varied, but most of these plates made successful holograms when they had a second chance!

III. HOLO-GNOMON

The gelatin can be dissolved off completely disastrous plates in a bath of sodium hypochlorite, better known as laundry bleach. The obvious use for such a plate would be to cap a good hologram, using a reliable epoxy or optical adhesive. Or a hole can be drilled through the center with a diamond bit, a nail stuck through it, and then a Xerox copy of Figure 1 can be glued to it for a handy reference beam angle measuring device! At 45° from the nail/normal, the shadow of the nail will be as long as the nail is tall. A circle whose radius is equal to the nail's height would identify a 45° incident beam if it were coming from top, bottom, left or right or anywhere inbetween! Figure 2 shows the trigonometric relationships of the radii of the concentric circles with respect to the angle for those who like to draw their own. The nail/normal is dubbed a gnomon, like the shadowcaster on a sundial.

The uses for this device are many fold; measuring beam angles is a lot better than guesstimating them. Different reference angles for different sections of large collages can be coordinated. Shrinkage angles of triethanolamine concentrations can be measured. Angles of incidence for solar-powered environmental installations can be charted during the course of a day over the period of a year.

It can also be an aid to composition if the nail were piercing a transparent substrate like glass or plexiglass. The holographer would know when they are looking smack dab into the middle of the scene along the normal if only the head and none of the shaft of the nail is visible. Off-normal viewing angles can be sighted as in Figure 3.

This may be a good time to discuss adopting these devices to standardize nomenclature for hanging holographic displays. The rings name the angle of incidence measured from the normal. To describe the direction, I suggest using the hours on a 12 hour clock in the best fighter pilot jargon tradition--i.e., 45 degrees from the top would be 45° from 12 o'clock high. But because the shadow is contrary to the source this requires an upside-down counterclockwise face. The last coordinate, distance of the source from the hologram is all that needs to be known to replicate conditions at the holographer's studio out in the field. To avoid any confusion the holographer could include a nail and the card with its shadow drawn on it when the hologram is shipped. Then there would be no excuse for the display crews not to hang it properly!

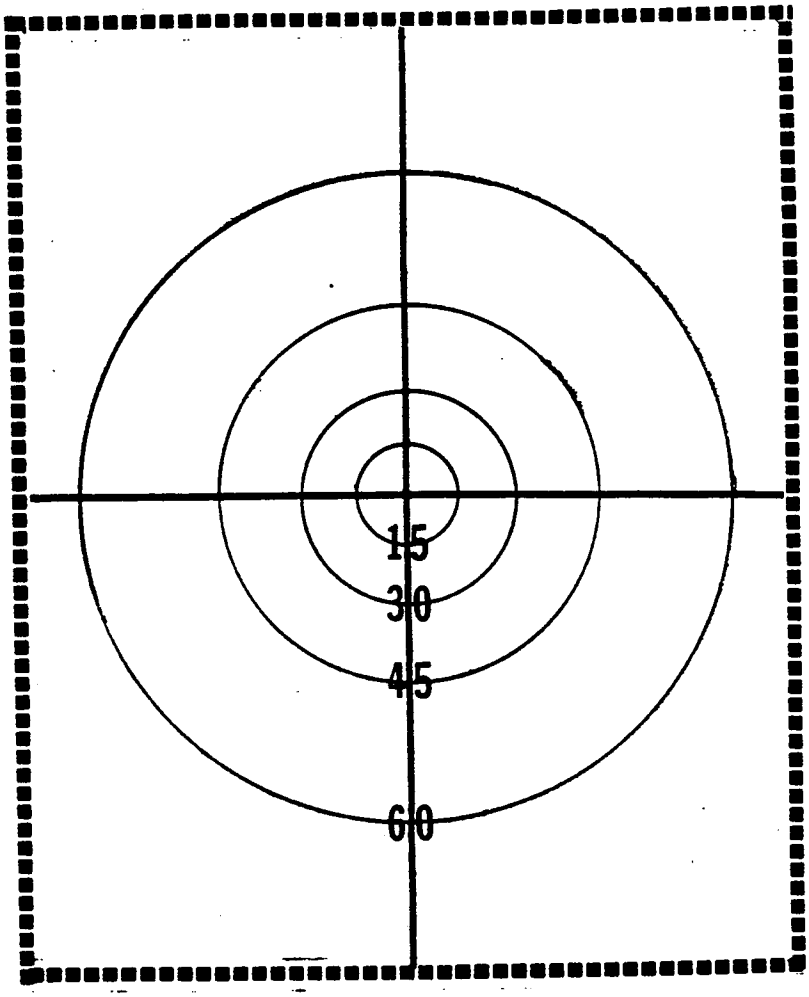

Figure 1. Whatever is used for the gnomon must be perfectly perpendicular to the plate and must extend 25 millimeters from the surface for this calibrated set of circles.

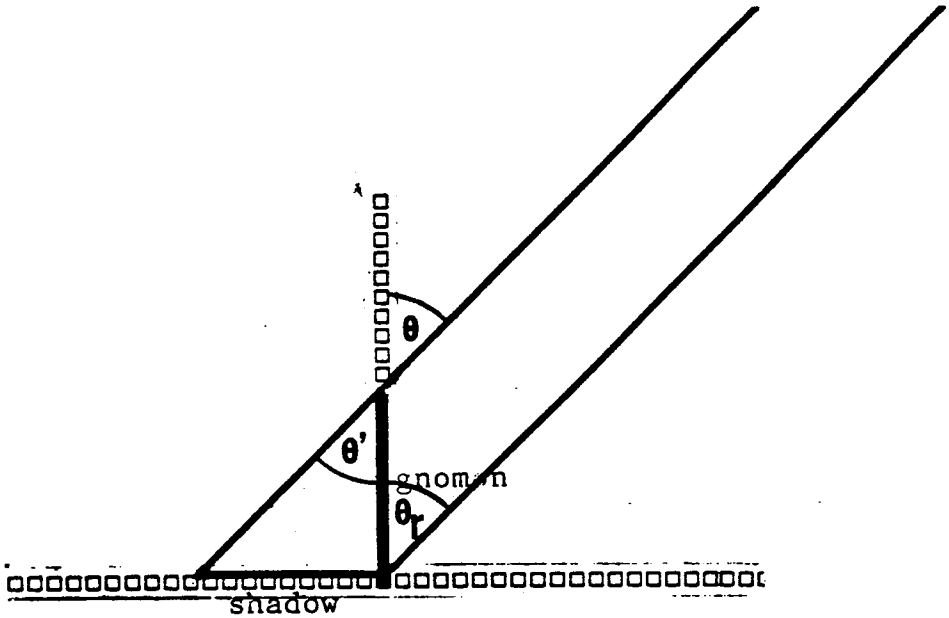

Figure 2. $\theta_r = \theta$ if the incident beam is collimated. $\theta = \theta'$ by the Vertical Angles Theorem. Then Length of Shadow = Length of Gnomon times tan θ_r.

Accuracy to better than 1° for a 25mm gnomon is ensured if the reference beam is more than 1.03 meters away. The proof of that is left to the reader. (Hint: Use the Law of Sines.)

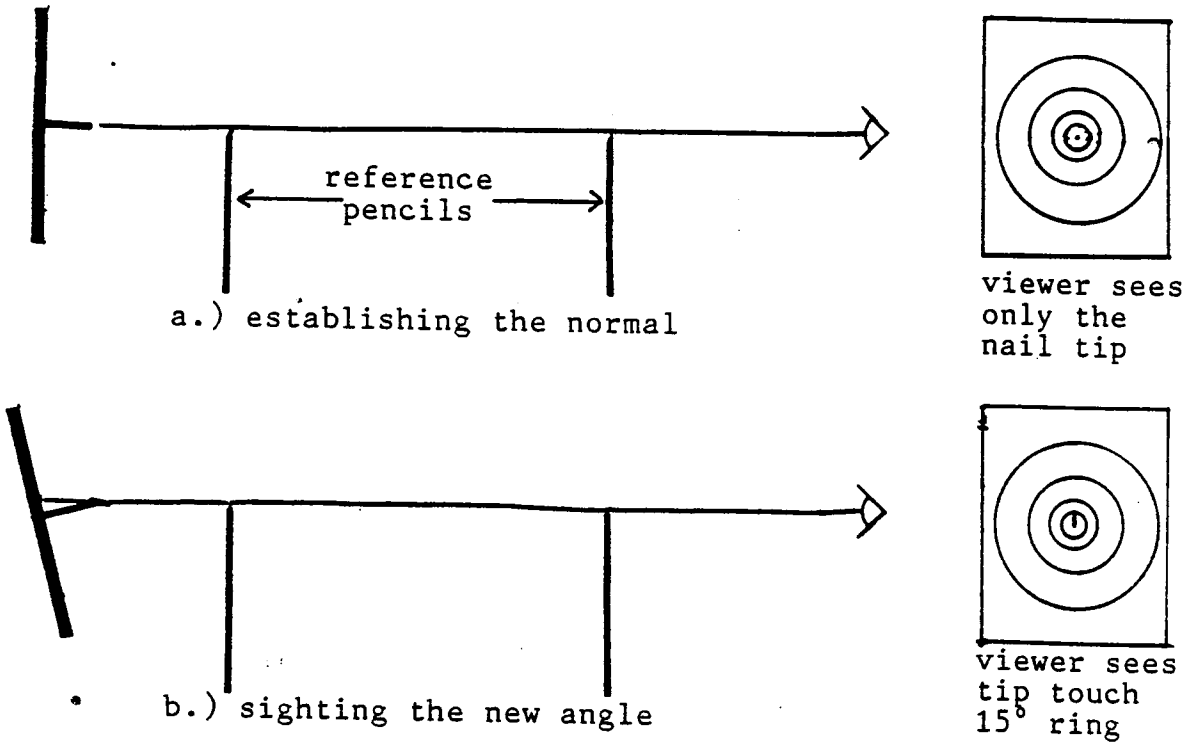

Figure 3. To determine off-normal viewing angles, first establish a normal line of sight using two reference pencils. Tilt plate so that gnomon touches desired angle's ring, for instance the 15° "Ward" angle.[3]

TABLE I. SILVER HALIDE PROCESSING FORMULAE

Fe EDTA Bleach
30 g Ferric Sodium EDTA
30 g Potassium Bromide
10 ml Sulfuric Acid
1 litre Water
Adapted from: Philips, N. J., holosphere Vol. 14, No.4, p. 21.

CWC2 Developer and PBQ2 Bleach

Developer	Bleach
10 g Catechol	15g Citric Acid
5g Ascorbic Acid	50g Potassium Bromide
5g Sodium Sulfite	2g p-Benzoquinone (Beware!)
50g Urea	1 litre Water
30g Sodium Carbonate	
1 litre Water	

From: D. J. Cooke and A. A. Ward, Applied Optics Vol. 23, No. 6. p.934. The Fe EDTA bleach can be substituted for the PBQ one. Development time, 2 minutes @ 20°C.

Simple Ferric Nitrate Bleach
150g Ferric Nitrate
30g Potassium Bromide
1 litre Water
Dilute 1 + 4 before use
This is the Agfa recipe GP431, holding the phenosafranine.

Stain Remover S-13

Bath A	Bath B
2.5g Potassium Permanganate	10 g Sodium Bisulfite
8ml Sulfuric Acid	1 litre Water
1 Litre Water	

One minute in each bath @ 21-27°C
From R. L. Lamberts and C. N. Kurtz, Applied Optics, Vol. 10, no. 6, p. 1342.

TABLE II. SENSITOMETRIC DATA FOR ERASED PLATES

Sample	Relative exposure to uncalibrated white light			
	1X	2X	3X	4X
Virgin Emulsion	.23	.41	.95	1.88
Fe EDTA erased	.21	.44	.89	2.20
PBQ erased	.23	.73	1.81	3.25

density units

TABLE III. PRE-EXPOSURE PREPARATION OF GELATIN PLATES DERIVED FROM AGFA 8E75HD

1. Fix in 10% Sodium Thiosulfate solution for 15 minutes.
2. Wash in running water for 15 minutes.
3. Wash in Methanol for 10 minutes.
4. Wash in clean Methanol for 10 minutes.
5. Soak in hot water (90°C) for 6 to 12 minutes.
6. Sensitize in 5% Ammonium Dichromate solution for 2 minutes.
7. Air dry.

All steps at 20°C except where noted.
From J. Oliva, P.G. Boj, and M.Pardo, Applied Optics, Vol. 23, No. 2, p.196.

TABLE IV. PROCESSING SCHEME FOR AGFA DERIVED DCG PLATES

1. Soak in Kodak Rapid Fix with ¼ hardener for 2 minutes
2. Soak in Photo-Flo 200 solution, 43°C, 5 minutes.
3. Soak in 30% water, 70% isopropanol, 53°C, 5 minutes.
4. Soak in 100% isopropanol, 70°C, 5 minutes.
5. Dry rapidly in warm air.

During testing, the processing devolved to 30" to 1' soaking times at room temperature with no change in the final hologram.
From S. P. McGrew, SPIE Vol. 215, p. 24.

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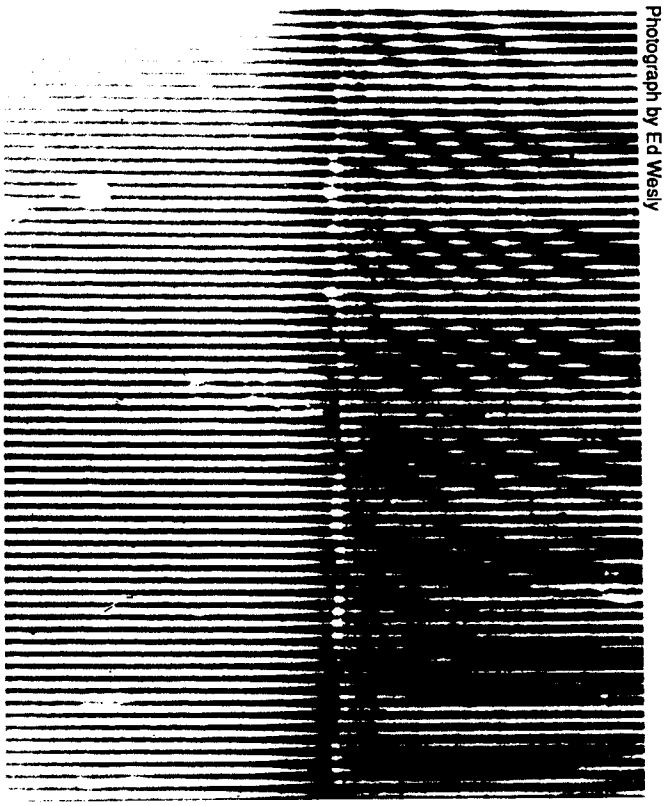
ANTIHALATION BACKINGS

Ed Wesly



Photograph by Ed Wesly

The left-hand side of this HOE was backed with #33; the right was not. Notice the random wood-grain pattern and the regular internal reflection ringing on the right.

Whenever light encounters the boundary between two different media, it is always reflected as well as refracted, except for the special case of polarized light incident at Brewster's angle. This *Fresnel reflection* depends on the difference of the refractive indices of the two media and the angle of incidence of the light. (See *Optics Guide* 3 by Melles Griot, pages 174-175, for details.) Fresnel reflection occurs not only for light entering the glass, but also for light exiting the glass into the air. This internal reflection from the back boundary becomes a nuisance when it meets up with light entering the first surface—the waves interfere, causing the familiar "wood grain" pattern to appear in the developed plate. Bleaching back to transparency can hide this cosmetic noise, but it would be nice to eliminate it at the source. How can a barrier be put inside a piece of glass to prevent light from returning from the back side?

Because photographic light sources are usually not coherent, photographers do not have to deal with that moiré wood-grain pattern, but they face a similar problem. Internal reflections can cause sources of light to look as if they have halos around them, so antihalation backings are added to the film to improve image sharpness.

Antihalation backings have the same (or nearly the same) refractive index as the glass or film substrate in order to effectively couple the exiting light. If there is no change of refractive index, then there is no Fresnel reflection and all the light proceeds as if it were still in the substrate. The backing should also absorb the light sufficiently to avoid light reflecting from the antihalation layer/air boundary. The layer need not be too dark, since it does double duty attenuating light heading for the exit boundary and extinguishing whatever little bit is reflected on the pass back through the antihalation layer. Black would be a good panchromatic absorber, while blue, green or cyan would be effective for red lasers. Kodak is currently the only manufacturer of backed films and plates. At an informal poll taken at the 1985 International Symposium on Display Holography, an almost unanimous show of hands should have proved to the Agfa reps that there is a demand for 8E75 HD films and plates with backing, which they discontinued with the introduction of the HD series of emulsions in 1979.

There are various homemade antihalation solutions. A piece of black paper or cloth placed behind the plate is not a very satisfactory antihalation backing since it is neither of the same refractive index as the glass nor is it in intimate contact with it. Sometimes single-beam reflection images of the card can be seen in the final hologram. John Perry of Holographics North in Vermont uses black Speedball Screen Print Ink not only as an antihalation backing but also as an adhesive to attach the film to glass. But this creates quite a mess when washing off the ink, which should not touch the gelatin because it likes to stay there. Working with it in the dark requires a lot of care.

Black water-soluble hair spray like that sold in novelty and costume shops seemed like a good solution to me, but the hair spray wouldn't stick to the glass very well and ran like crazy. Paints, greases and index-matching tanks have been tried, but a solution that is easy,

cheap, effective and fun to use has been suggested by Doris Vila of the Art Institute of Chicago. You know what a thrill it is to strip the plastic protective coating off a fresh front-surface mirror with a piece of tape—this same coating works well as an antihalation backing! (Incidentally, I know of a Ph.D. candidate and his professor who didn't know this freshman trick and attacked the skin of the mirror with a variety of solvents and French curses!) The stuff is known as #33 Metal Blocking Spray and is available from Universal Photonics Inc. (495 West John Street, Hicksville, New York 11801; phone: 1-800-645-7173). Besides coating optics, it can also be used in layout work on metal, so similar products from the machine shop may also work.

Lacking a refractometer to see how well #33 index matches glass, or a densitometer to check its absorbency, other means of evaluation were required. A simple test of effectiveness for any antihalation backing is to look for fringes in the light reflected from a backed plate onto a white card. No fringes mean that light is being reflected only from the first surface, and that also suggests the use of the glass as a weakly reflecting "black mirror" to lower the ratio in a single-beam transmission setup with the reference mirror near to the object. The most practical test is to make a hologram on a plate that is only half backed. The photograph shows the wood-grain pattern superimposed on a rather low spatial frequency grating on the uncoated side of such a plate.

Spray the #33 on in a well-ventilated area or under a fume hood. The plates should be lying on a flat, absorbent surface so that any runs will be wicked off and soaked up before leaking under and spoiling the emulsion. Accidents can be pulled off with tape, but it's best to prevent this, since the spray seems to desensitize the emulsion. A couple of "dry" sprays from afar are better than one done closer, which may turn thick and runny. A bonus of spraying is that the edges of the plate will be covered, so taping them is unnecessary to prevent that dreaded internal reflection ringing. The liquid can also be used to attach film to glass; however, don't spray directly onto a piece of acetate film, since a mild solvent action will distort it.

The improvement in the image is certainly worth the effort, but the easiest solution would be to be able to buy plates and film already AH'd. Now all we need is for someone to find a cheap, clear, nonflammable, nontoxic liquid for attaching film to glass for making reflection holograms.

ADDENDUM: There is a companion product to #33, called X-59 Strippable Coating, which is a black brush-on version of the above. There is still a strong solvent smell, but it is localized at the glass surface. Nevertheless it is best to use this product under a fume hood or in a room with good ventilation, plus using a respirator with both organic and spray paint filters.

The best way to apply this goo is with a foam rubber brush. These things are cheap enough to toss out after being destroyed by the solvent. Regular brushes leave streaks and are almost impossible to rid of the X-59. Mayer Bars are good to use if they are available.

These products can be put to good use in cleaning large front surface mirrors! Simply spray or brush on, let dry, and when you peel off the plastic sheet you will remove all the dirt and fingerprints with it! Or leave it on while the optics are being shipped or remain in storage.

Universal Photonics now has a WATS number, 800-645-7173.

BLACK BACKINGS

Reflection holograms look so much more solid if there is a black ground behind them so that the real world is not seen through them. (Except in certain cases, like creating the paradox of seeing two objects occupy the same space through the superimposition of object and holographic image as seen through the transparent holographic plate. Viz. the work of Frithioff Johansen or Mary Harman*, for instance.)

There are a variety of ways to reach this goal. The most obvious approach is to paint the back of the plate or film black. The choice of flat versus gloss black paint is immaterial, since the paint is viewed through the glass or film base, and both types of black look the same in that mode. The glossy paints look blacker than flat when viewed on the outer surface because they dry with a smooth surface skin and are fairly good specular reflectors; all the images of the light sources in the area follow the angle of incidence = angle of reflection rule and are diverted from the eye, unless the surface is tilted to deliver the light into the eye. But flat paints dry with a random texture, which is a diffuse reflector, always delivering some of the incident light to the eye. Although the two types of paint may have the same amount of pigment in them, a side by side comparison will reveal the flat as appearing more of a charcoal grey color as opposed to the infinite void blackness of the glossy, because it sends more light to the eye than glossy. Photographic prints with a glossy surface look more contrasty than the same image on matte paper for the same reason; the diffusely reflecting surface weakens the darkness of the shadow area by filling it in with extra light. But both types of paints when applied to a piece of glass look the same when viewed through it since they have taken on the smoothness of the back inner surface.

If the paint is applied to the glass surface of the hologram, it should be happy there for a very long time. But painted applied to the emulsion side raises the eyebrows of archivists, as the long term effect of the paint on the gelatin is unknown. **Spray Paint** consists of a propellant, to get the stuff out of the can; solvents to keep the pigment suspended in a medium, which evaporate to leave the pigment in a hardened medium on the surface.

Black pigment is typically carbon black which is inert; the real danger is in the solvent. When the emulsion of a silver halide hologram is spray-painted, the big pigment molecules congregate on the surface, but the smaller solvent molecules work their way into the gelatin, swelling it up like water, so the hologram

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*. Pay attention during the **HOLOGRAPHIC ARTISTS A-Z Lecture.**

disappears temporarily, since the Bragg planes are plumped up to reflect in the infrared rather than the visible. If it were to do any damage to the emulsion this would be the time, because it evaporates out of the emulsion eventually. The hologram takes much longer to dry after being painted than it does having been wetted with water, because the solvent evaporates from the top of the painted surface first, leaving a skin that is harder for the rest of the solvent rising from the depths of the emulsion to permeate. The more paint put on at once, the longer it takes before the hologram becomes visible again. Several light coats are better than one thick application.

To prevent painting the emulsion, the hologram could be exposed so that the emulsion is toward the viewer during reconstruction, and then the uncoated plastic or glass base is painted. The naked emulsion could be covered with a plain piece of glass. If the emulsion ends up away from the viewer, a black-painted piece of glass, with its painted side away from the emulsion could be incorporated into the framing sandwich.

If for some reason a holographic plate gets painted on the wrrong side, or if there are some paint splotches on the wrong side, use acetone to remove the paint. Don't use acetone on film; it will slightly dissolve the triacetate, although that could be a neat effect.

Something to play with is using a color other than black as the opacifying agent. A red image can be contrasted with a green or blue backdrop for a different viewing experience.

There are commercially available black contact papers that incorporate an index-matching adhesive layer to attach it to the hologram, followed by the black plastic, with another adhesive layer to attach it to its intended site. The **SUPERNATURALS** series of holographic toys are the major example of this material. It is manufactured by Mac-Tac and Seal, major suppliers of photographic mounting supplies. It was designed to be used as part of the **Applied Holographics Holo-Copier System**, and may not be readily available any more.

Incorporating a piece of black backing material behind the hologram when framing it obviates the need for applying anything archivally eyebrow-raising to it. The search for the perfect medium continues, but black velvet works quite well as a light trap, although it is expensive.

The **Blood Bath** is a chemical method of darkening the emulsion, although it is not pure black like paint. The red-developed colloidal silver is somewhat transparent, the background is not totally blocked, but it does present an improvement.

SODIUM HYPOCHLORITE

is better known as Laundry Bleach. It is like **Holographic Bleaches** in that it does oxidize or bleach something, but its oxidizing effects on **Holographic Plates** can be quite devastating. One of its functions in the **Holographic Chemical Cabinet** is to remove the emulsion from unsuccessful holograms so that the glass can be used for other things. The duds are placed in the bleach and it is so much fun to see the gelatin coating just melt off. A quick rinse and the plates are ready to be used as cover glasses, to accept a DCG coating, or whatever.

Another job for this chemical is removing stains not from clothes but from the holographer, **pyrogallol** stains in particular. This developing agent tans gelatin as it works, which is pretty much the same thing as skin. So to get rid of those tell tale pyro fingers, a brief dunk in the bleach will get your digits Saturday night spic and span.

But remember what this stuff did to the holographic emulsion, and you can feel its effect on you by the hardening of the skin after bleaching. Try to minimize the need for this use and you'll be happier for it. Otherwise rinse the laundry bleach off, wash with soap and water, and use a good skin cream to replace the moisture in the hands.

HOLOGRAPHIC FILM AND PLATES PRICE LIST*
(Agfa 8E75HD)
List Prices, June 1995

FILM	PLATES
2.5" by 2.5"	
N/A	1 box (30 units) = $100.80 1 unit = $3.36
4" by 5"	
1 box (100 units) = $172.00 1 unit = $1.72	1 box (20 units) = $162.90 1 unit = $8.15
8" by 10"	
1 box (100 units) = $703.00 1 unit = $7.03	1 box (10 units) = $315.05 1 unit = 31.51
30 by 40 centimeters	(approximately 12" by 16")
1 box (50 units) = $818.00 1 unit = $16.36	1 box (10 units) = $702.60 1 unit = $70.26
50 by 60 centimeters	(approximately 20" by 24")
1 box (25 units) = $1,027.00 1 unit = $41.04	N/A

If buying less than full boxes, you must furnish your own light tight container.

THE BYZANTINE PROCESS OF BUYING HOLOGRAPHY SUPPLIES WITH THE SAIC HOLOGRAPHY DEPARTMENT RESALES ACCOUNT

As with all the **Resale Accounts** in other **SAIC Departments**, you must go to the **Utrecht Store** in the **Champlain Building****. They will not take charge cards for Resale Account Purchases, cash or check only.

We will give you the original and a copy; a second copy remains in our receipt book. We will total up the supplies, they will add on the tax. After paying them, they will keep the original and stamp the copy **"PAID"**. Bring this back to us, so we can acknowledge that the transaction was completed and staple it into our receipt book and give you the supplies.

Remember, "I owe, I owe, it's off to **INCOMPLETE-Land** I go!"

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* Prices subject to change. Since we must sell the material for the same price we paid for it, the actual current price is posted right on the supply box.

** 37 South Wabash Avenue, 2nd floor.