CWC2

CWC2 is the moniker for a developer which was introduced in the March l5th, 1984 issue of Applied Optics[1] in an article by D. J. **C**ooke and A. A. **W**ard, 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 the fringe spacing as more of the exposed and developed silver was removed in the bleaching. But the **CWC2** developed and **CWPBQ2** bleached

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[*] See the **Handout, PYROCHROME**.

[**] See the **Handout, EXPOSURE DOSES**.

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 GP6I**[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 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

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

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** 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

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

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

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[*] For **C**ooke-**W**ard **P**ara-**B**enzo**Q**uinone Number **2**. They called the previously published **GP432 PBQ**-based formula **PBQ1** in their article.

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

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

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

[**] **E**thylene **D**iamine **T**etra-**A**cetic 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.

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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23. A handout circa 1979 from Integraf, (Dr. Jeong's personal business) prescribed developing in Kodak D-8 or D-19 and bleaching in a bath composed of 2 grams Potassium Dichromate, 2 milliliters of Sulfuric Acid, and 30 grams of Potassium Bromide in a liter of water. Mixing the basic 'Chrome bleach (4 g Potassium Dichromate and 4 ml Sulfuric Acid) with an equal part of a 6% solution of Potassium Bromide would produce the bleach above. Care should be taken to use only 'Chrome bleach that has never bleached material, as the dissolved silver compounds floating in it would precipitate in the holographic emulsion. This bleach formula yields results just as bright as any others mentioned in this handout, except that it seems to be slightly 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.