EFFECTS OF DRY ETCHING TECHNIQUES ON CHANGING HALFTONE DOT-SIZES

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Abstract: This paper describes an investigation into the effects of dry etching techniques on changing halftone dot-sizes. First, the process of dot etching and the alternative method of dry etching are described. Then, details of the study are presented. The growth of halftone dots are compared on films subjected to several levels of exposure manipulation by three contact printing techniques used in dry etching. Two types of graphic arts film are compared; as are three different halftone originals. Observations, conclusions and recommendations drawn from this study are presented.

Background of Dot Etching

Since the 1920's, local color corrections on halftone films have been made by "dot etching" techniques borrowed from the earlier repertoire of the photoengraver. Dot etching relies on strong oxidizing solutions (historically potassium ferricyanide) to reduce the silver density on selected parts of the halftone film. First, portions of the film are protected with an acid resistant staging applied in liquid form by brush or airbrush. Once the staging has dried, the film is immersed in the etching bath. Either a one-bath or a two-bath method is used depending on whether sodium thiosulfate (fixer) is added to the solution or used separately. The oxidizing agent converts metallic silver to a silver salt; the fixer dissolves the salt. The film is then washed; the staging is removed, and the set of separations is reproofed to judge the effects of the dot etching.

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Today, this time-tested method is becoming inadequate to meet the demands of a rapidly expanding market for color printing. Some of the problems plaguing dot etching are the following: First, the process is slow; the application of the staging is time-consuming and often repeated treatments are required. Second, there is the danger of overetching the film and causing that separation (or the whole set) to be remade. Third, dot etching does not work well with laser exposed films, which are coming into increased use. Fourth, the chemicals used in dot etching present health and safety concerns. Fifth, sometimes visible "staging lines" are imaged on the reproduction showing the boundaries of the acid-resistant coating. Sixth, the process does not lend itself to calibration since the chemical activity of the etching solution changes rapidly. Seventh, dot etching offers no control over contrast, and it has the effect of reducing contrast in the treatment area. Eighth, the dot etcher is a highly skilled craftsperson combining accurate color judgement, a mastery of brush and airbrush techniques, and a thorough understanding of the etching process. This is not a work force easily subjected to quick expansion to meet surges in demand. These negative factors suggest a need for an alternate way to make local color corrections.

Ideally, the need for color correcting after halftone generation can be circumvented by using sophisticated video systems like the Sci Tex Response 300, the HCM Chromaskop, or the Crosfield 570 System. These systems enable color correction operations, along with many others, to be performed electronically with the aid of a high resolution video color monitor. The image on the monitor is adjusted to match the effects of printing, and the operator can manipulate that image to attain desired results. Electronic image processing is developing rapidly, and potentially it can reduce the need for after-the-fact color corrections; however, it does not offer a direct alternative to dot etching for making local corrections to existing halftones.

Introduction to Dry Etching

Dry etching, also known as "dry dot etching" or "photographic color correction", offers an alternate means for performing color corrections on halftone separation films. Dry etching utilizes contact printing techniques, and it is based on the theory that a perfect dot-for-dot copy of the faulty color separation can be deliberately varied to yield a corrected halftone film.

The procedure for dry etching (Figure 1) is as follows:

1. A mask is produced (photographically and/or by hand) which isolates the treatment areas. This isolation mask is used to give an added "corrective" exposure during one of the two contact printing stages which follow.
2. A contact print is made from the halftone separation yielding a dot-for-dot copy which is tonally and laterally reversed. For color corrections of increased color for separation negatives, or decreased color for positives, an additional exposure must be made through the isolation mask causing enlarged dots in the treatment areas.
3. A second dot-for-dot contact print is made from the intermediate negative produced in step two. If less color for negatives or more color for positives is desired in the treatment areas, than the corrective exposure through the isolation mask is made during this stage. The film which results from this step is the corrected halftone separation.

There are at least three means for applying the corrective exposure during the dry etching process. The first and most prevalent technique is to use simple overexposure with the isolation mask in place. A second method, specifically for large dot-size changes, utilizes a clear spacer film (0.004 inches thick usually) between the halftone and the graphic arts film during the corrective exposure but not during the dot-for-dot exposure. The third technique is to use exposure through the base of the graphic arts film for at least

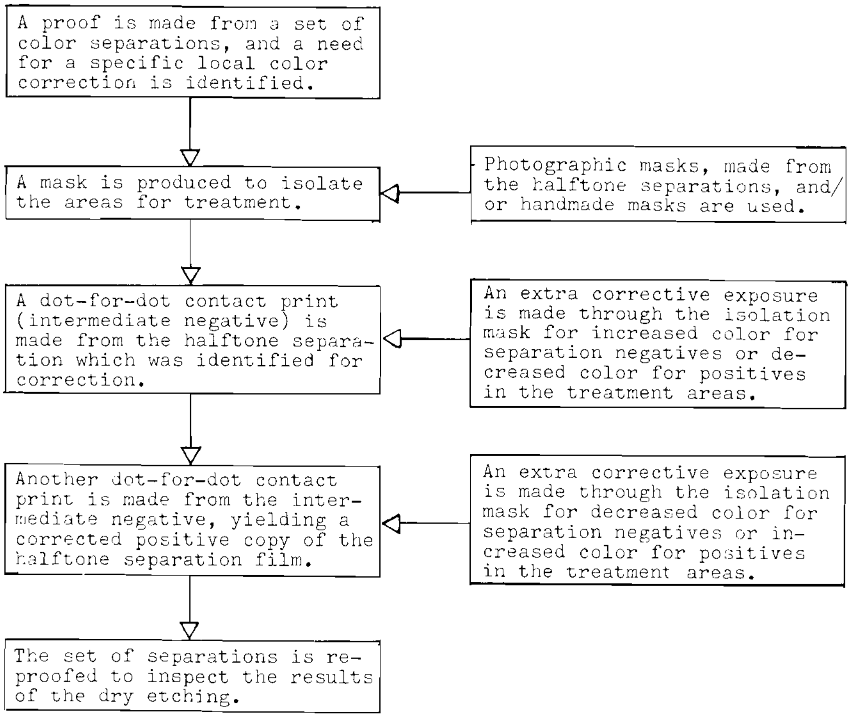

Figure 1. Procedure for Dry Etching

part of the corrective exposure. These techniques are diagrammed in Figure 2.

Isolation masks are not always used during dry etching. When overall increase or reduction of a color is required no mask is needed. Also, the photographic printing techniques of "dodging" and "burning-in" can be employed in place of an isolation mask for some corrections.

Isolation masks are made by contact printing the separation halftones out-of-focus on negative-acting or duplicating films. The exposure can be varied to register different tones as clear or solid on the contact print. There are six different combinations representing negative and positive versions of the three primary color separations. Often two or more films are put together to form an isolation mask, and, at times, a hand cut Rubylith film is added to the composite

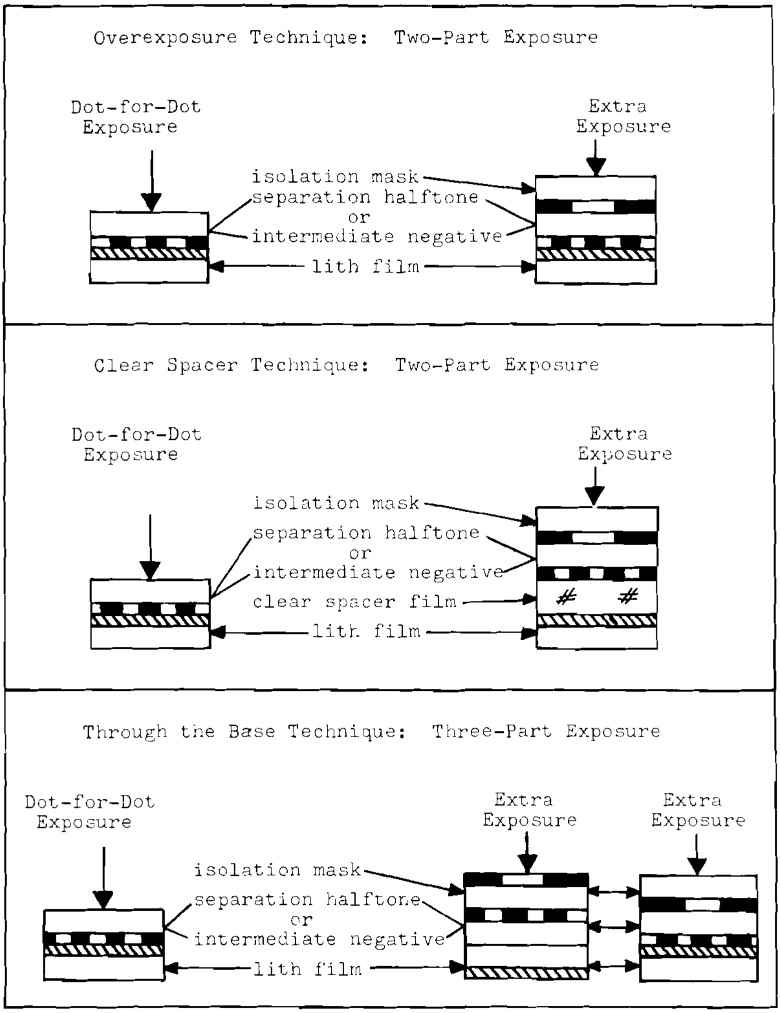

Figure 2. Corrective Exposure Techniques

to isolate specific areas. Mask combinations used for isolating specific colors are listed in Figure 3.

To isolate	Masks required
red	Cyan pos + Yellow neg + Magenta neg
green	Magenta pos + Yellow neg + Cyan neg
blue	Yellow pos + Cyan neg + Magenta neg
cyan	Cyan neg + Magenta pos + Yellow pos
magenta	Magenta neg + Yellow pos + Cyan pos
yellow	Yellow neg + Magenta pos + Cyan pos

Figure 3
Mask Combinations for Isolating Colors

To isolate colors between the hues listed only two films are usually required in the masks.

Dry Etching vs. Dot Etching

Dry etching compares favorably with dot etching on many points. First, dry etching is faster than wet etching for many corrections. Second, there is no danger of destroying the original separation during the dry etching process; this enables the color corrector to make bold moves in achieving desired results. Third, dry etching works well with hard-dot films. Fourth, no hazardous or toxic chemicals are required for dry etching. Fifth, the problem of staging lines in the reproduction is avoided. Sixth, dry etching systems can be calibrated for predictable results. Seventh, manipulations of contrast within the treatment areas are possible with dry etching by imaging different amounts of detail on the isolation mask. Eighth, the color corrector using dry etching does not need to have the highly developed skills, with brush and airbrush, which are required in the dot etching process. And, finally, larger dot-size changes can be made with dry etching than are possible with dot etching.

In contrast to the advantages of dry etching cited above, there are several disadvantages to its use for making local color corrections. First, film costs are high; several full size sheets of film are required for each dry etching correction. Second, dust control is difficult since several films are combined together to form some masks, then contact printed with the separation halftone. Third, for some corrections it is time-consuming and difficult to make the required isolation mask. Fourth, dry etching requires that strict quality control measures be followed with respect to the contact printing system and the chemical activity of the automatic processor. Sixth, since a perfect dot-for-dot copy of a halftone film is unattainable, there are small changes in color that occur in non-treatment areas during dry etching.

The color correctors interviewed during this study agreed that dry etching works better than dot etching for many of their corrections. However, most shops using dry etching are also using traditional dot etching for a portion of their jobs. The method of color correction used is determined by the requirements of each job and the preferences of the individuals involved.

Experimental Factors

In this study the effects of six factors were compared with respect to dot-size changes during contact printing manipulations. Multiple levels of each factor were considered as listed in Figure 4.

Experimental Procedure

Three different scanner generated 150-line halftone gray scales were used in this study. The first was made on a Hell DC-300B scanner at the RIT School of Printing. The dots were formed by an Argon laser through six individually modulated optical fibers. Two scans are required for each dot. The dots are "hard" with no appreciable fringe area. The second halftone scale (donated by Case-Hoyt Co.) was generated on a PDI Compudot scanner; the laser formed dots are "semi-hard" with a small amount of fringe area. The third halftone scale (donated by Rochester Polychrome Co.) was from a Crosfield 510 Magnascan; the dots in this case were formed by a glow lamp through a contact screen, and they are "soft", having

Factors	Levels				
Halftone Originals	Hell (hard dots)	P.D.I. (semi-hard dots)	Crosfield (soft dots)		
Dot-Areas Being Manipulated	5%	25%	50%	75%	95%
Technique of Dry Etching	Over-exposure	Exposure through film base	Use of clear spacer film		
Degree of Corrective Treatment	1, 1.25, 1.5, 2, 3, 4, 6, 8, 10, 15, 20, 30, 40, 60, 80, 100 times dot-for-dot exposure				
Type of Film	Rapid Access	Lith Film			
Contact Printing Phase	original-to-intermediate negative	intermediate negative-to-duplicate positive			

Figure 4. Experimental Factors and Levels

appreciable dot fringe.

Target dot values were identified (with a MacBeth Dot Area Meter) which approximated 5%, 25%, 50%, 75%, and 95%. The actual target dot-sizes are listed in Figure 5.

Hell	6	25	49	75	95
PDI	8	23	49	75	93
Crosfield	3	22	49	73	95

Figure 5. Original Target Dot-Sizes

The halftone scales were then assembled together on a masking sheet, and this test object was subjected to a series of trial exposures to determine the best dot-for-dot exposure times for each halftone original by each of three contact printing methods (emulsion-to-emulsion, 4-mil spacer film between emulsions, and through-the-base) on both lith and rapid access films (Dupont COD-4 and Dupont RAF). All exposures were made on a Berkey Ascor Contact Printing frame with an integrated point-light source. All films were processed through Dupont automatic film processors with recommended Dupont chemistries. The developer activity was kept within control limits throughout the experiment.

Initially, contact prints were made at one unit increments by each method of contacting on both film types. The target dot-sizes on the resultant films were read and entered into Dot-for-Dot Exposure Tables. The differences between target and actual dot-sizes were calculated and entered into Dot-for-Dot Variability Tables. The variances from target values for each of the test films were summed across the five target values. The exposure times which resulted in the best dot-for-dot fit were then identified for positive-to-intermediate negative copies.

The best dot-for-dot intermediate negatives for each halftone original (emulsion-to-emulsion) were assembled together on masking sheets to form test objects for the intermediate negative-to-duplicate positive phase of the experiment. Two such test objects were produced, one for lith film and the other for rapid access. The dot-for-dot calibration was then repeated for the second generation of contact printing.

The test objects (both positive and negative) were subjected to a series of overexposures(treatment levels) via each contact printing method considered. The treatment levels were determined as factors of the best dot-for-dot exposures. The levels were 1, 1.25, 1.5, 2, 3, 4, 6, 8, 10, 15, 20, 30, 40, 60, 80, 100 times dot-for-dot exposure. The intermediate negative and the duplicate positive phases were treated separately, as were the Hell, PDI, and Crosfield originals and, the two film types used.

The dot-sizes of the resulting films were read and entered into tables showing the effects of exposure manipulation. From this data the net dot-size change due to overexposure was determined for each contact printing technique/film combination.

The next phase of the research was to establish dot-size change limits for each contact printing technique. To accomplish this microphotographs were made of the test films at 80 times original size on continuous tone film. Prints made from these negatives were presented together with the test films to selected evaluators who identified the point at which each series of treatments resulted in dot structures of unacceptable commercial quality. The microphotographs acted as a guide to suggest which films required closer examination. The evaluation of unacceptable dot structure was, in every case, made by visual evaluation of the test films themselves. The responses were averaged to determine the upper limit for each dry etching technique tested.

Dot-Size Growth

The data was used to construct a series of graphs depicting the net dot-size growth for all contact printing/film combinations up to an exposure manipulation of 10X. Sample graphs, all relating to changes associated with 75% original

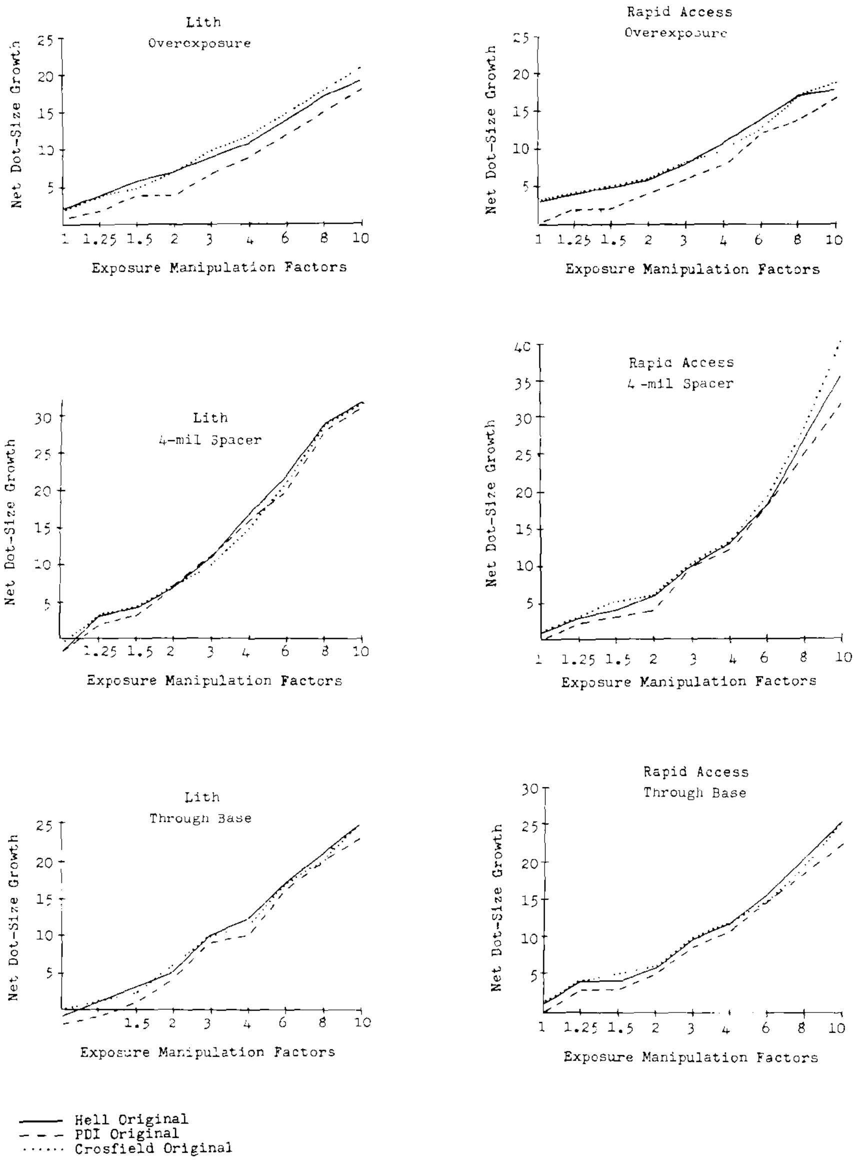

Figure 6.

Net Dot-Size Growth -- 75% Original

dot-sizes, are presented in Figure 6. The series is restricted to the intermediate negative phase of contacting. The responses of the three halftone originals are depicted on each graph.

An examination of all the dot-size growth graphs lead to the following observations:

1. No clear difference was distinguished between the dot growth patterns of the three different halftone originals. There was an apparent difference for the 5% original dot-size, but this can be attributed to the actual differences between the three original dot-sizes which approximated 5% (6% for Hell original, 8% for PDI original, and 3% for Crosfield original).
2. The rapid access film responded more quickly to exposure manipulation than the lith film.
3. The use of a 4-mil spacer caused quicker response in dot growth than the other contact printing techniques.
4. Dot-for-dot copying from small original dot-sizes was less successful for the technique of exposing through-the-base than for the other two contact printing techniques.

Maximum Dot-Size Changes

A second series of graphs was constructed showing the maximum acceptable dot-size change throughout the scale for each contact printing technique. Sample graphs are presented in Figure 7 showing the maximum dot growth for the PDI original. Separate graphs were made for each original, graphic arts film, and contact printing phase.

Examination of the entire series of graphs lead to the following observations:

1. The positive-to-intermediate negative phase exhibited more capacity for dot-size change than the intermediate negative-to-duplicate positive phase.
2. Lith film exhibited greater capacity for dot-size manipulation than rapid access film.
3. With lith film, the use of a 4-mil spacer

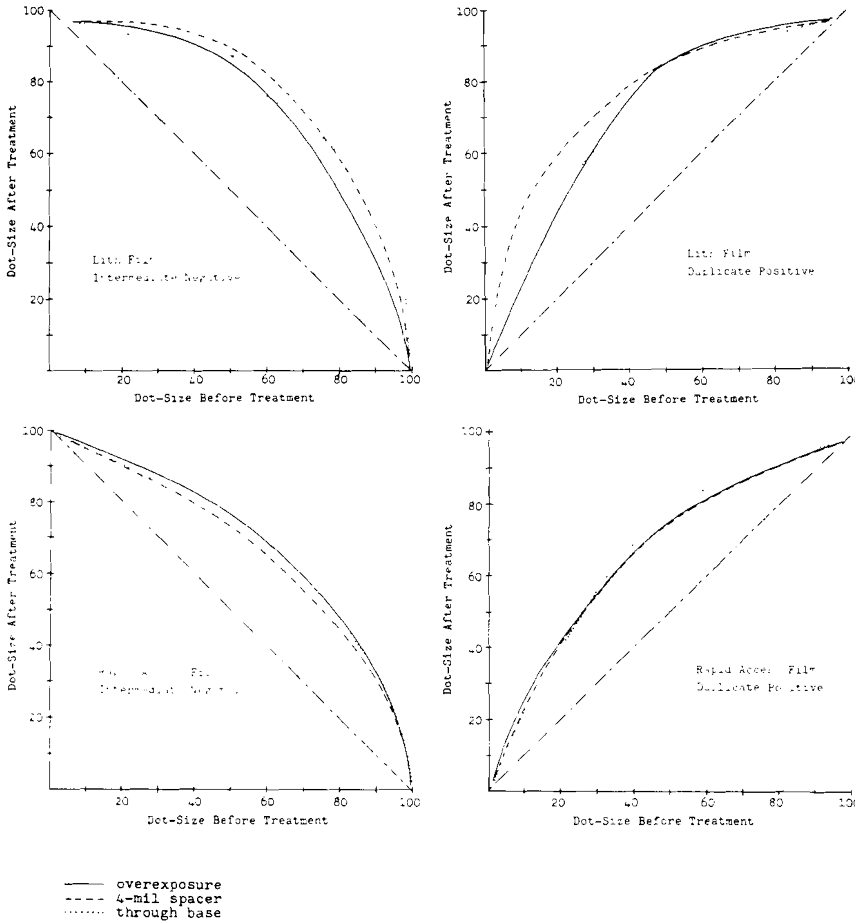

Figure 7

Maximum Acceptable Dot-Size Changes
PDI Original

resulted in the largest acceptable dot growth.

4. The maximum acceptable dot growth was not uniform throughout the scale. A non-symmetrical relationship was characteristic, skewed slightly towards the lower end of the scale on the original film.

Acceptable Dot-Size Changes

The universes of acceptable dot-size changes for each combination of contact printing technique, film system, halftone original and contact generation was assembled into a series of tables, a sample of which appear in Figure 8.

Hell original
Overexposure technique
Lith film
Intermediate negative

Exposure Manipulation Factors	original dot sizes 6	25	49	75	95
1	94	76	53	27	5
1.25	95	79	57	29	5
1.5	95	79	58	31	6
2	96	82	60	32	7
3	98	85	64	34	8
4		87	66	36	8
6		90	71	39	9
8		92	75	42	10
10			78	44	10
15			85	52	12
20			88	56	12
30				67	14
40					16

Resultant Dot-Sizes

Figure 8.
Acceptable Dot-Size Change

Acceptable dot-size change tables could be used to predict exposure manipulation factors required to make specific dot-size changes, or they could be used to judge the feasibility of making large dot-size changes. Also, the color corrector would know what effect changing one dot-size by a prescribed amount would have on other original dot-sizes. However, the validity of predictions made from these tables is restricted to the specific printing system used to establish the tables, and it is dependent on the repeatability of that system.

Analysis of Variance

An analysis of variance (ANOVA) technique was used to compare the effects of four factors on maximum dot-size growth. This technique was used since it allows multiple factors and their interactions to be tested simultaneously. The factors considered in this ANOVA were identified in the following manner:

Factor I (films) = A_i,
where i=1 (lith), 2 (rapid access)

Factor II (originals) = B_j,
where j=1 (Hell), 2 (PDI), 3 (Crosfield)

Factor III (technique) = C_k,
where k=1 (overexposure), 2 (spacer), 3 (through base)

Factor IV (tonal orientation) = D_l
where l=1 (negative), 2 (positive)

The completed ANOVA table for the 50% original dot-size is presented in Figure 9.

The results of the ANOVA table for the 50% original dot-size indicated the following:

1. At the 90% confidence level all four factors considered in the analysis did cause significant variability in attaining maximum dot growth. Giving direction to these differences leads to the findings that: lith film exhibited greater halftone growth capacity than rapid access film; the PDI original resulted in larger acceptable dot-size changes than the Hell or Crosfield originals; the intermediate negative phase allowed dot-size changes of a greater magnitude than the duplicate positive phase; and the use of a spacer film produced the biggest acceptable dot changes of the contact printing techniques tested.

2. At the 90% confidence level, a significant interaction was detected between the contact printing technique and the graphic arts film used. With lith film the technique of exposing through the base exhibited far less capacity for dot growth than the other two techniques, but the differences were greatly reduced with the rapid access film used. This is probably due to differences in their

source of variability	sum of squares	degrees of freedom	mean square	F ratio	F_0 $\alpha = .10$	results	F_0 $\alpha = .05$	results
A_i	971.36	1	971.36	130.21	4.54	*	7.71	*
B_j	285.50	2	142.75	19.14	4.32	*	6.94	*
C_k	87.92	2	43.96	5.89	4.32	*	6.94	NS
D_l	250.69	1	250.69	33.60	4.54	*	7.71	*
$(AB)_{ij}$	63.39	2	31.70	4.25	4.32	NS	6.94	NS
$(AC)_{ik}$	88.97	2	44.48	5.96	4.32	*	6.94	NS
$(AD)_{il}$	0.26	1	0.26	0.03	4.54	NS	7.71	NS
$(BC)_{jk}$	9.58	4	2.40	0.32	4.11	NS	6.39	NS
$(BD)_{jl}$	51.73	2	25.86	3.47	4.32	NS	6.94	NS
$(CD)_{kl}$	14.97	2	7.48	1.00	4.32	NS	6.94	NS
$(ABC)_{ijk}$	36.53	4	9.13	1.22	4.11	NS	6.39	NS
$(ABD)_{ijl}$	1.15	2	0.58	0.08	4.32	NS	6.94	NS
$(BCD)_{jkl}$	58.86	4	14.72	1.97	4.11	NS	6.39	NS
R_{ijkl}	29.84	4	7.46					
Totals	1950.75	35						

* – indicates significance

NS – not significant

Figure 9.
ANOVA Table -- 50% Original Dot Size

anti-halation backings.

3. None of the other interactions tested were found to be significant; however, the F-ratio of the AB interaction was close to significance. This implies that the type of graphic arts film used and the type of halftone original may be interdependant. Specifically, it appears that the Crosfield original (soft dot) performed particularly poorly (compared to the other originals) on rapid access film but not on lith film.

4. At 95% confidence the technique of contact printing used, and the interaction between that and the graphic arts film employed, were not found to be significant sources of variability in effecting maximum dot growth.

The findings of the ANOVA's for the 5% and 95% original dot-sizes generally supported these conclusions. ANOVA's were not performed on the 25% and 75% originals.

Recommendations for Further Study

The nature of this study was that of an initial investigation into the effects of dry etching. Further studies would be useful to examine some of the factors considered here with more precision, as well as to investigate new topics. A few examples follow:

1. The repeatability of dry etching might be tested by replicating a series of dry etching manipulations several times and analyzing the results for variance.
2. Acceptable dot quality could perhaps be objectively rather than subjectively scaled. A scanning microdenditometer could be used to read the test films, and tolerances for background fog and the slope of the dot fringe tracing might be used to indicate acceptable dot quality.
3. The effects of underexposure, used by some dry etchers, could be examined.
4. The effects of split exposures, emulsion-to-emulsion and through the base, could be tested across a range of fractional splits.

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