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Photography and Photogravure: History of Photomechanical Reproduction

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ABSTRACT. The first practicable photomechanical system-contact-screen photogravure-was invented in 1852 by W. H.F. Talbot of England. Many of the approaches introduced by Talbot are still used in current practice: contact cross-line "master" and "working" screens: metal plate etching through a bichromated gelatin emulsion: etching with ferric chloride solutions of different concentrations: and selective local etching for "retouching" purposes.

To provide the tiny image ink-holding components in the printing plate, Talbot used fine gauze fabrics for the contact cross-line screens and fine resin particles (aquatint) applied as a powder or liquid. He also experimented with contact screens of ruled lines on paper: scored cartilage: waxed paper with scribed lines: aquatint pattern on paper and a blackened film with uniform grid of clear circular openings.

INTRODUCTION

By 1852, the year in which the first practicable photomechanical system was introduced, two different approaches had been devised-heliogravure (1826), and chemically etched daguerreotypes (1839). Heliogravure had several major disadvantages, i.e., low light sensitivity, not adaptable to recording continuous-tone subject matter, and a soft surface which would not withstand the wear and pressure imposed by printing presses. Chemically etched daguerreotypes required the services of a highly skilled practitioner and retoucher. As with heliogravures, daguerreotypes did not incorporate a wear-resistant surface; their relatively soft, silver-coated copper plate did not withstand the tremendous pressure repeatedly imposed by presses and the number of prints a plate could produce was limited.*

In May 1839, four months after the photographic processes of Louis Jacques Mande Daguerre (daguerreotypes) and William Henry Fox Talbot (photogenic drawings) were made public, English-born Mungo Ponton described the results of his own experiments :which, 13 years later, were incorporated into the first practicable photomechanical approach. Ponton coated paper with a solution of potassium bichromate, placed an object on the surface and exposed it to light. Exposure changed the normally deep yellow tones of the coating to a deep orange in regions receiving the greatest amount of light. The image was "fixed" by a water wash which removed the yellow, unexposed regions.

Ponton noted that "light not only changes its [potassium bichromate] colour, but deprives it of solubility, thus rendering it fixed in the paper."[1] He noted that light sensitivity of this coating was insufficient for camera exposures but adequate for photogenic drawings (photograms) and contact printing. Ponton demonstrated that the spectral sensitivity of potassium bichromate was principally in the violet portion of the spectrum and, in this respect, similar to silver chloride. It should be noted that he never referred to the use of gelatin as part of his light-sensitive system-an approach which was essential to the photomechanical system devised in 1852 by Talbot.

The earliest observation noting the light sensitivity of potassium bichromate when mixed with an organic substance was published in 1832 by Dr. Gustav Suckow, professor, University of Jena.[2]

Although Ponton was at a loss to suggest a practical application for his process he did express hope that some way would be found to use it in the field of lithography. He also pointed out that his technique employed a low-cost material (potassium bichromate)[3]-a factor which, much later, encouraged its adaptation to large scale photomechanical operations.

Other investigators such as Edmond Becquerel of France[4] and Robert Hunt of England[5] subsequently experimented with potassium bichromate hoping that they too could find some practicable photographic or photomechanical application for this light-sensitive compound. Their contributions, however, were eclipsed by Talbot's 1852 and 1858 inventions.

The system devised by Talbot, linking the negative-positive photographic image (introduced by him in 1839 and patented in 1841 and 1843)[6] to the photomechanical technique (patented by him in 1852 and 1858)[7] inaugurated a vast new field offering rapid, mass visual communication of graphic information. Shortly after this technological breakthrough of 1852 a deluge of different "systems" poured forth. Some of these approaches adapted and varied Talbot's techniques but many were completely new. Within 25 years various photomechanical approaches began to gain acceptance in the printing

* A full description of these two techniques can be found in Ostroff's, "Etching, Engraving and Photography: History of Photomechanical Reproduction" in the previous issue of this publication.

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industry, eventually proving adaptable to large-scale, high-speed production techniques.

Photomechanical Patent, 1852

Briefly, Talbot's patented procedure[8] is as follows:

1. Clean a steel printing plate with vinegar containing a little sulphuric acid.
2. To a gelatin solution "of moderate strength" add saturated solution of potassium bichromate (2:1) and spread on plate. Dry by heating gently. Alternatively, coat plate with aquatint,[9] then apply bichromated gelatin emulsion.
3. Overlay sensitized plate with subject, e.g., lace or sprig; place in contact printing frame; expose to sunlight, ½- 5 or more minutes.
4. Remove unhardened (unexposed) emulsion by water immersion, 1 - 2 minutes; dip in alcohol 1 minute, dry.
5. Etch in saturated solution of bichloride of platinum containing a little free acid and dilute with water 4:1. Note image change from orange to dark black in 1 - 2 minutes.
6. Remove remaining gelatin by rubbing with wet sponge or cloth.
7. Printing procedure - same as that used for plates produced by the hand processes. Talbot also proposed that zinc plates and lithographic stones could be used.

Contact-screen photogravure* was introduced by Talbot in this same patent (modification section). He proposed contact printing the emulsion-coated metal plate twice. The first exposure is made through two or three layers of a finely woven fabric, such as gauze, all layers at different angles with respect to each other in order to provide a maze of intersecting lines. After removing the screens, a second exposure is made to a leaf or through a positive image on paper or glass. After these exposures the plate is treated as described before, i.e., washed, etched, cleaned and dried. In this same patent Talbot advocated using emulsions made of albumen, gum arabic, "or mixtures of these and other analogous substances in various proportions."

Photomechanical Patent, 1858

Talbot in his second invention dealing with photomechanics (1858)[10] expanded the type of plate materials to include copper, changed the etching solution to ferric chloride and introduced a new approach to photogravure-photoaquatint. The procedure was as follows:

1. Coat metal plate with gelatin solution (¼ oz. gelatin: 8-10 oz. water + 1 oz. saturated solution of potassium bichromate).
2. Contact print lace, leaf, print from an engraving, photograph, etc., 1 - several minutes.
3. Remove plate from contact printing frame and dust with powdered copal,* a natural resin. Gently heat plate to soften the resin grains and make them adhere to the emulsion.

Iron chloride served as Talbot's etching solution and a unique arrangement was devised for using this medium. Three different concentrations were prepared:

1. saturated solution
2. 5 or 6 parts saturated solution: 1 part water
3. 1 part saturated solution: 1 part water.

The reaction of solution strengths were tested, in advance, on a sample plate. Interestingly, solutions of higher concentration produced slower etching actions, a phenomenon which will be explaine,l later.

One procedure called for applying solution No. 1 and then constantly brushing the emulsion surface with a camel's hair brus . If increased etching was needed in a particular area, solution No. 3 could be applied locally. This approach compensated for shortcomings of image tone which could not be corrected by a uniform etching technique; faint areas could be strengthened and shadow areas deepened. Etching action, according to Talbot, could be completed in two or three minutes. The remaining gelatin was removed by vigorous rubbing with a moistened, soft cloth, and the plate was inked, wiped, and printed.

A great economic advantage was gained by Talbot when he changed etchants from a costly platinum compound (1852) to the less expensive ferric chloride (I 858).

PHOTOMECHANICAL INNOVATIONS

Bichromated Gelatin

An outstanding feature of Talbot's first photomechanical patent (1852) was the use of a potassium bichromate-sensitized gelatin emulsion, coated on a steel plate. This coating displayed the essential characteristics of hardening and becoming insoluble when exposed to light. Talbot's earliest photomechanical approach employed pieces of lace, leaves or sprigs which were contact printed onto the emulsion for ½-5 minutes of sunlight. The plate was then dipped in water for 1-2 minutes to remove unexposed, unhardened emulsion and then etched in a solution of acidified bichloride of platina (platinum dichloride), a relatively safe etchant. It should be noted that until this time hand-made plates were chemically etched with the highly corrosive and dangerous nitric acid.

After a water rinse all remaining gelatin was removed by sponging. Plate inking and printing was done in the same manner as with heliogravures and etched daguerreotypes, that is, the surface was wiped clean of surplus ink before an impression was taken. Except for line work this procedure suffered from the same shortcomings of tonal fidelity as did the heliogravurt;s-intermediate tones could not be reproduced. In all etched areas, except those corresponding to narrow image lines where ink is confined and protected, it proved almost impossible to prevent some image ink frbm being removed during the ink-wiping operation. This resulted in an unpredictable tonal shift. (Fig. 1)

Talbot ingeniously overcame this primary obstacle by introducing the concept of contact, cross-line screens to produce, in the printing plate, ink-holding elements sufficiently small that ink would be protected during the ink-wiping operation. These and other features introduced by him established the basis of photogravure as we know it today.

For contact-screen photogravure work two exposures are made onto the emulsion beneath the screen openwork-first through the screen, and second, through the continuous-tone image.

Emulsion areas underlying the opaque screen lines receive only the single exposure to the continuous-tone image. With the latter image, darkest tones prevent light from reaching the bichromated emulsion, precluding hardening in these areas, while regions underlying the lightest tones, (i.e., highlights), receive optimum light transmissions, and hence, maximum emulsion hardening.

When etched, regions underlying the screen lines are affected in proportion to the amount of light transmitted in the single exposure through the continuous-tone image; areas corresponding to screen openwork receive little or no etching, having acquired optimum hardening during the two exposures. The hardened gelatin structure, corresponding to the clear areas of the screen, obstructs the etchant and protects the

*Photogravure, as used in this paper covers those methods which divide an image-usually continuous tone-into a uniform or random pattern of tiny components for printing purposes. This can be done before, during, or after the sensitized emulsion is exposed to the subject. The plate is then "processed" e.g., etched, to produce the ink-carrying depressions. Photogravure is an intaglio process, i.e., plate depressions comprising the image are inked, the plate surface is wiped clean, and only the ink remaining in these cavities is transferred to the paper.

*Copal is a resinous exudation from various tropical trees, especially of the genus *Copaifera*.

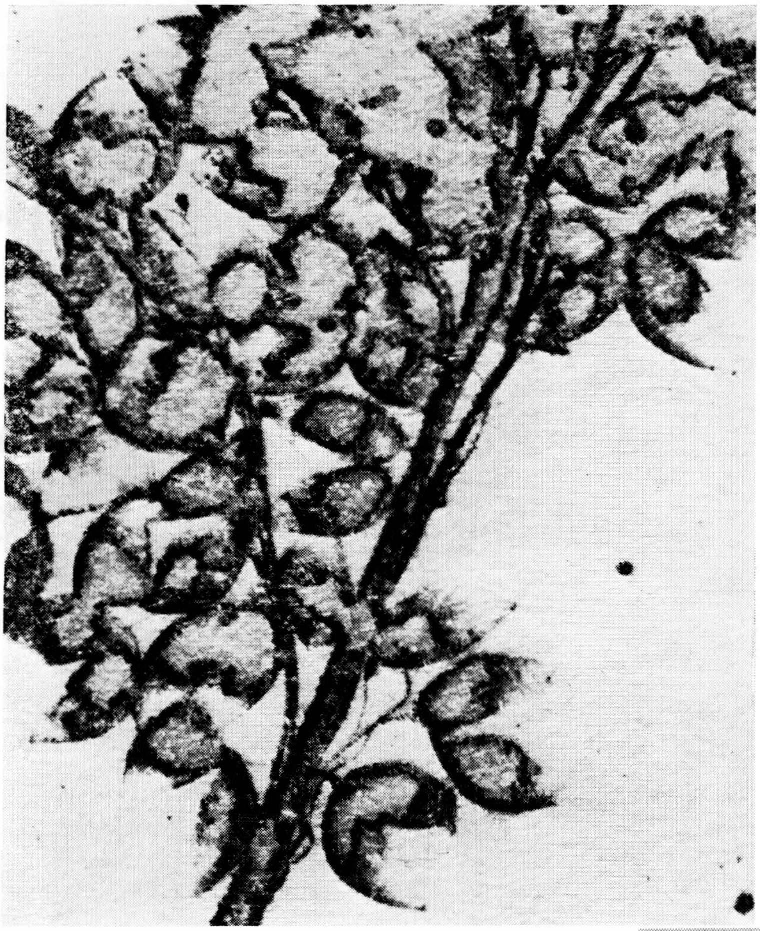

Fig. 1. Enlarged detail (10x) of Talbot photogravure (ca. 1852). Note ink removed from centre of broad image areas and retained only along narrowest lines (stem).
Burnett Brown collection.

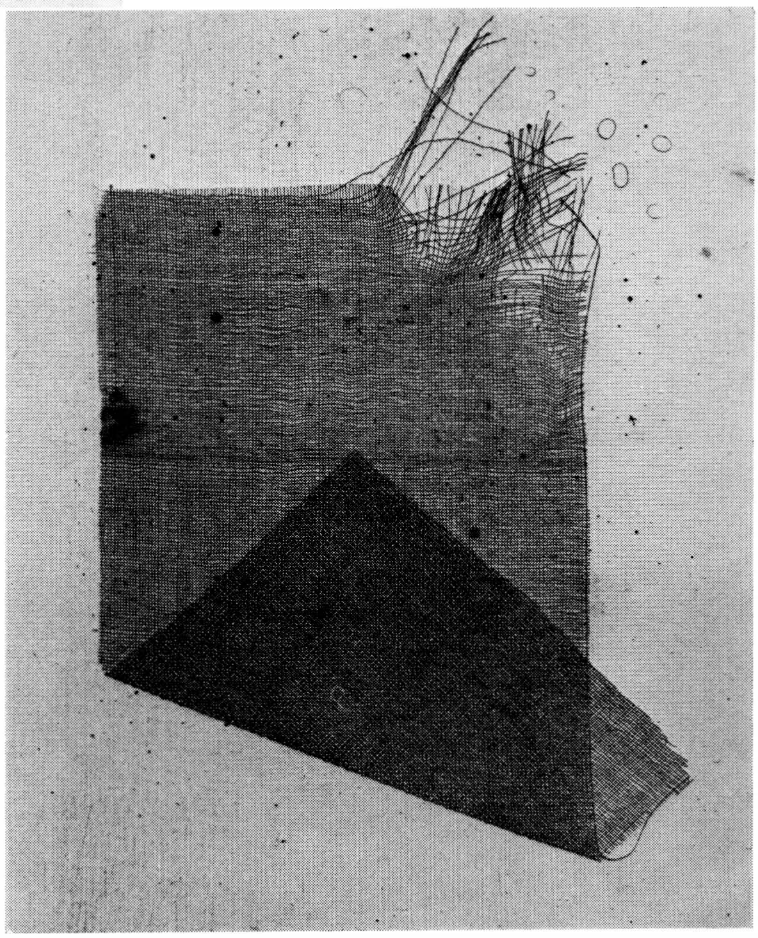

Fig. 2. Talbot photogravure print (ca. 1852) of gauze screen. The 45° fa/dover was used by Talbot to illustrate the effect of dividing a given area into a larger number of smaller, geometrically more complicated components.
Burnett Brown collection.

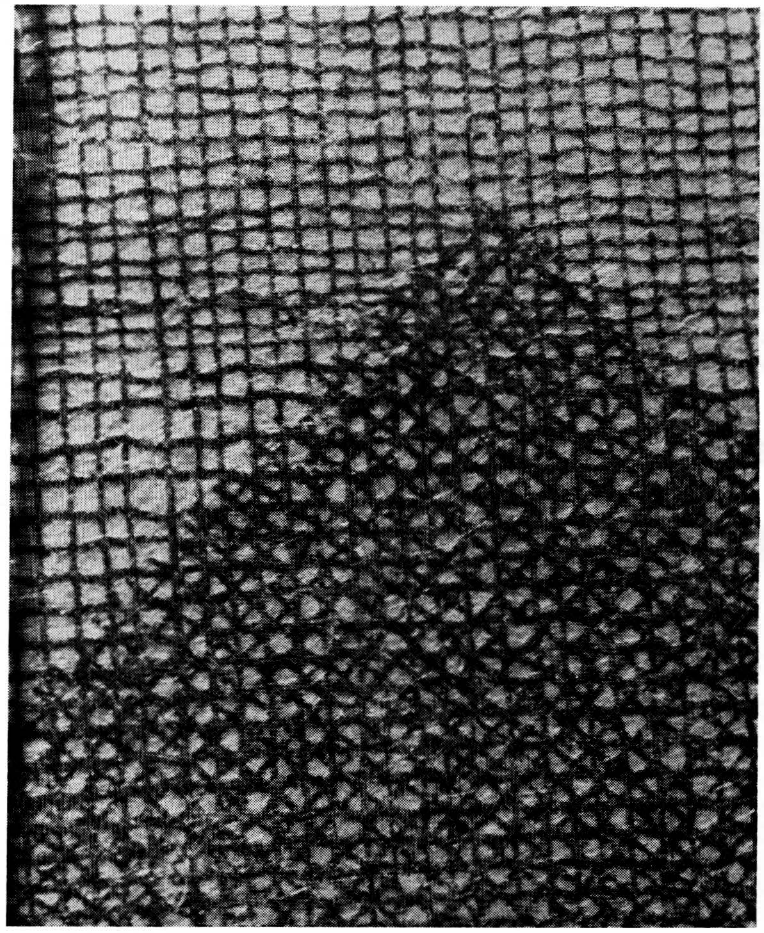

Fig. 3. Enlarged detail (10x) of print shown in Fig. 2. Note irregularities in gauze mesh.

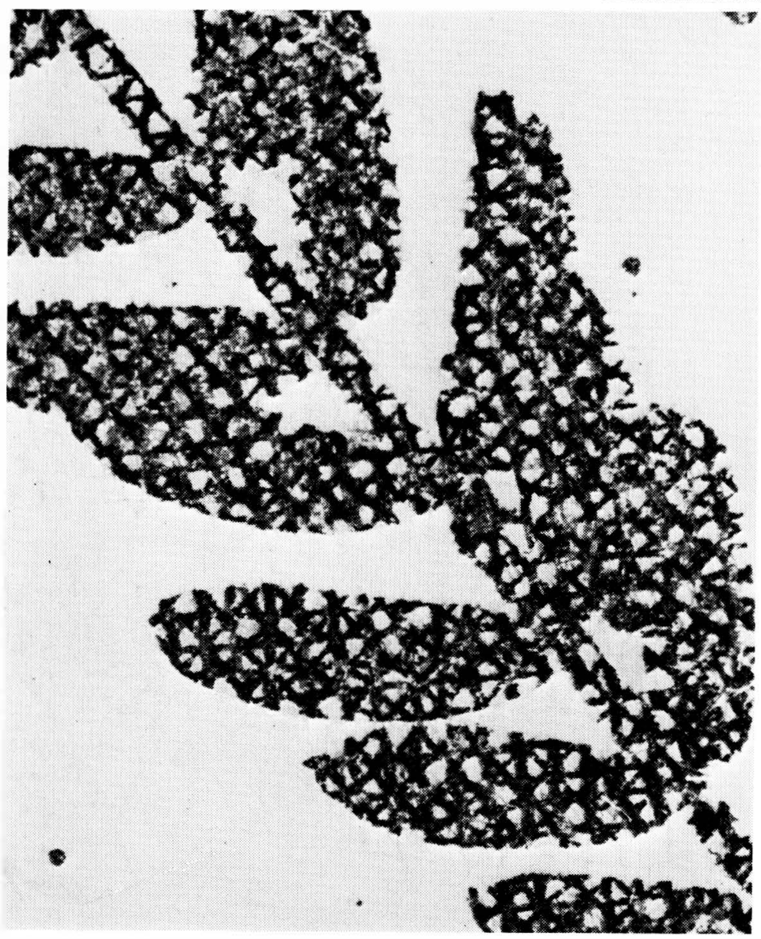

Fig. 4. Enlarged detail (10x) of Talbot photogravure print of flora (ca. 1852) illustrating use of crossed contact screens. Burnett Brown collection.

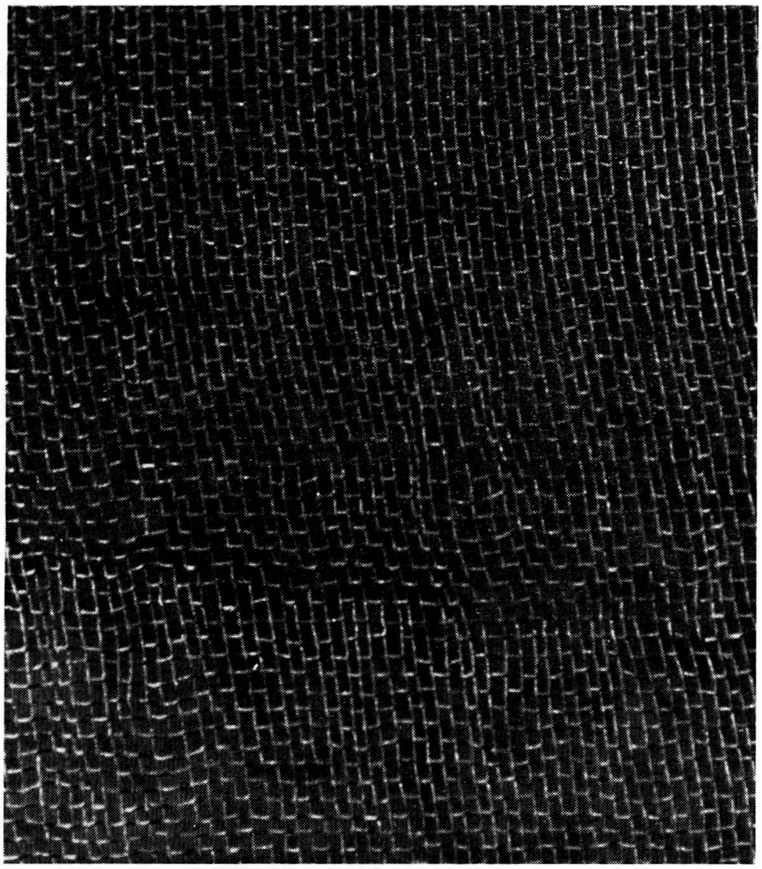

Fig. 5 Enlarged detail (Bx) of yellow gauze screen used by Talbot. Note similarity of mesh pattern with that shown in dig. 3. Dark background was used to help emphasize screen fibre details.

underlying metal. For convenience in simplifying this description we now introduce the terminology currently employed in the field: in reference to the printing plate, the rectangular areas within the grid lines, those etched by acid, are called *cells;* non-printing areas of the grid, those lying between the cells, are called *lands, bridges,* or *posts.*

After "development" (washing) there remain two images superimposed upon each other: the hardened gelatin relief of the screen openwork and the hardened gelatin relief corresponding to the continuous-tone positive transparency. The relief of this latter image exists in negative form, i.e., highlights (clear) areas result in the thickest gelatin deposit. The thickest layers of hardened geltin afford the maximum protection to underlying metal during later chemical etching (biting). Increasingly darker tones on the transparency result in thinner protective gelatin, with the thinnest being in the very darkest tonal areas. This arrangement permits the etchant to reach the darker tones more rapidly, and results in a deeper bite.

Image Dissection

Talbot found that contact cross-line screens could be used as a means of dividing the image into very small elements which, when etched into the plate, provided ink-holding reservoirs, or cells. Each of these elements, theoretically, should be capable of holding an ink volume necessary to produce an imprint density matching a corresponding area in the original, contact-printed subject matter. In practice !towever this was not the case and inaccurate tonal rendition had to be corrected by using etching solutions of different concentrations and the local application of etchants.

Another of Talbot's earliest efforts resulted in a photomechanical image illustrating his first screen-which was a piece of gauze (Fig. 2). He then applied the screen concept to silhouette-type subjects and demonstrated that black tones could be uniformly reproduced throughout an image area. After contact printing the screen onto the sensitized plate a leaf or a sprig was substituted for a second exposure. These experiments confirmed the practicability of using cross-line contact screens to produce ink retaining cells in the printing plate. Not being satisfied with silhouette images, he modified his technique and used, for the second exposure, continuous tone paper prints which were waxed or varnished; these coatings increased base translucency and reduced exposure time.

Talbot found that results were greatly improved by using two or three layers of gauze, each at a different angle (Figs. 3 and 4). His early approach of using a single screen resulted in a coarse, geometrically uniform pattern which could be observed on the finished photomechanical print. This rectangular screen pattern, frequently larger than some image detail, interfered with definition and proved to be very distracting. Talbot corrected this problem by using several screen exposures, or several layers of gauze, each at a different angle. This divided the image into a larger number of smaller components which, geometrically, were more complicated, making it less likely that the eye would resolve and distinguish any pattern when the print was inspected at a normal distance. This method significantly improved definition.

Talbot in 1852 also proposed other devices for segmenting the image: a line screen ruled on glass; powdered opaque particles on glass; or a plate coated with an aquatint before the gelatin coating is applied. Modifications of these latter two approaches were part of a technique variation covered in his 1858 patent.

In addition to the black gauze screen described by Talbot, he also used (1) yellow screens of gauze with rectangular pattern (Fig. 5), (2) yellow gauze embedded in a transparent flexible film which served to hold screen fibres firmly in place (Fig. 6), (3) ruled screens on paper (Fig. 7) and (4) a transparent flexible sheet of cartilaginous-like material (Fig. 8) containing nearly parallel, short, fine lines scored into both sides of the sheet (most probably blacking or ink was rubbed

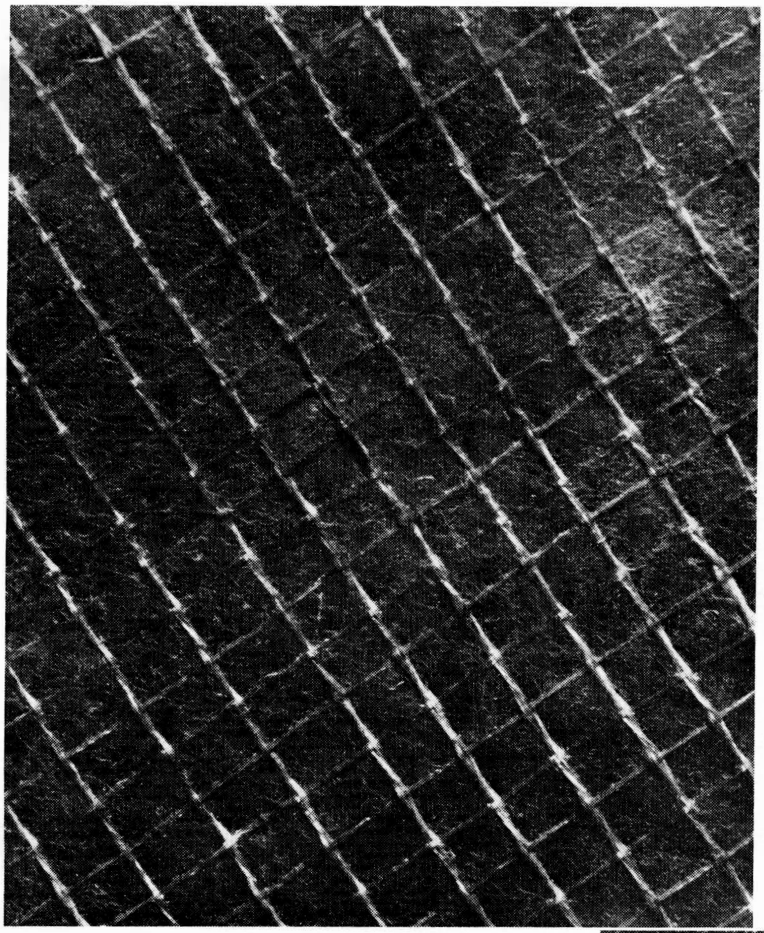

Fig. 6. Enlarged detail (12x) of Talbot's yellow gauze screen embedded in a transparent flexible film to hold fibres firmly in place. Areas between fibres are actually transparent but here they appear dark because reflected surface light was used to help emphasize screen fibre details.

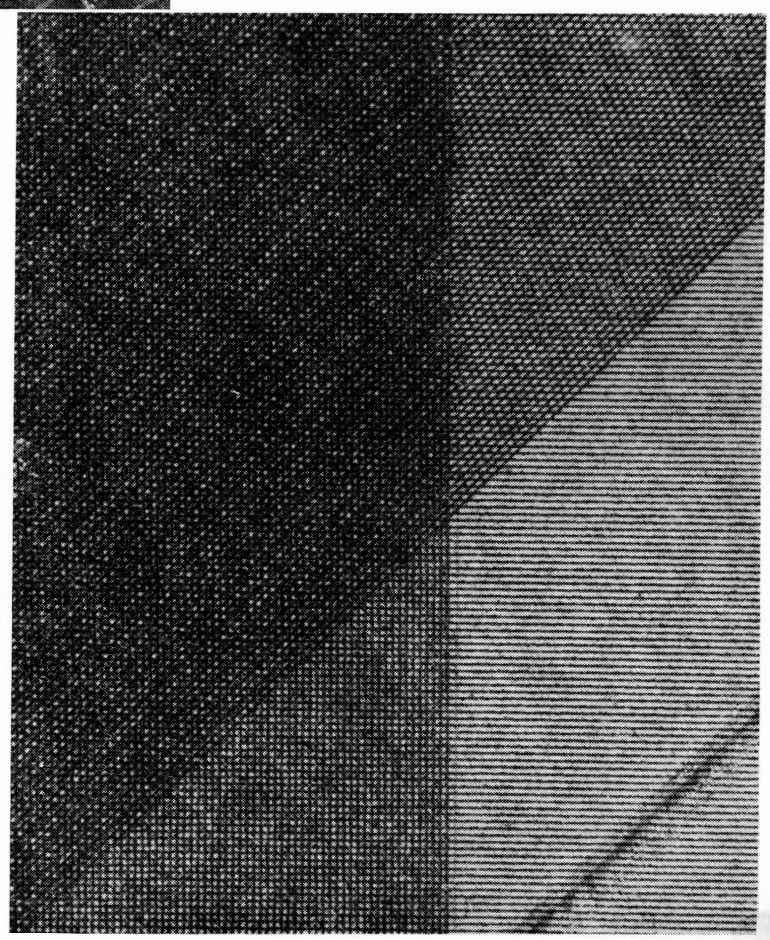

Fig. 7. Enlarged detail (10x) of Talbot's machine-ruled screen on paper. Corner is shown to demonstrate screen construction.

Fig. 8. Enlarged detail (10x) of a Talbot screen, a transparent, flexible sheet of cartilagionus-like material containing nearly parallel, short lines scored into both sides of sheet. Ink has been rubbed into a small area to illustrate appearance of opaque lines.

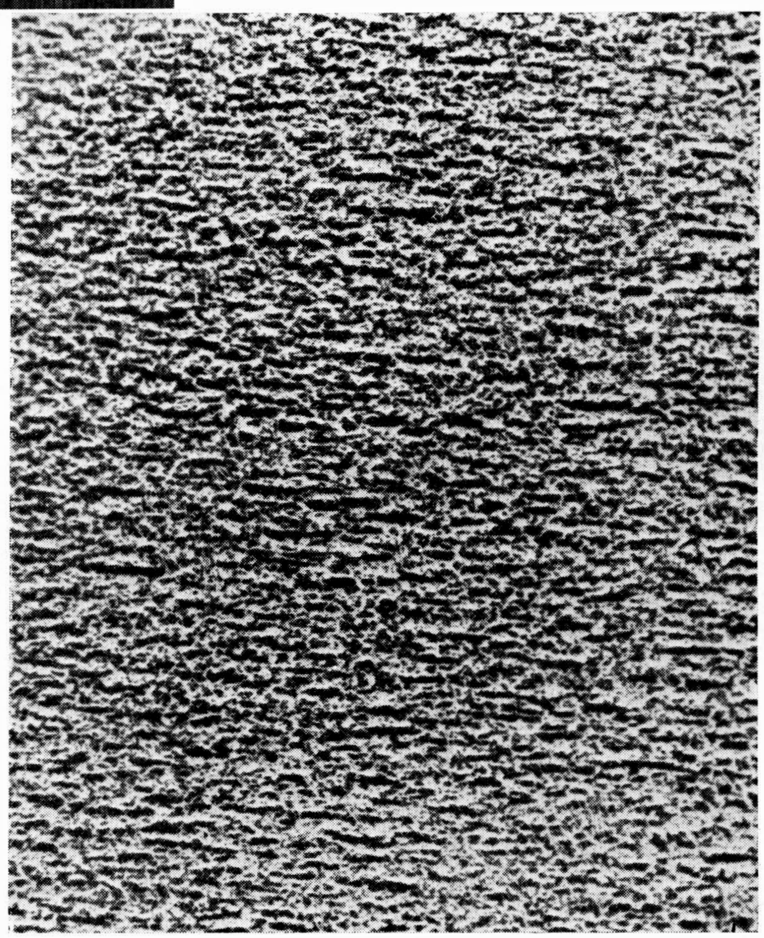

Fig. 9. Enlarged detail (10x) of a Talbot screen on paper: lithographic paper print (probably from crayon drawing on stone), waxed for improved translucency.

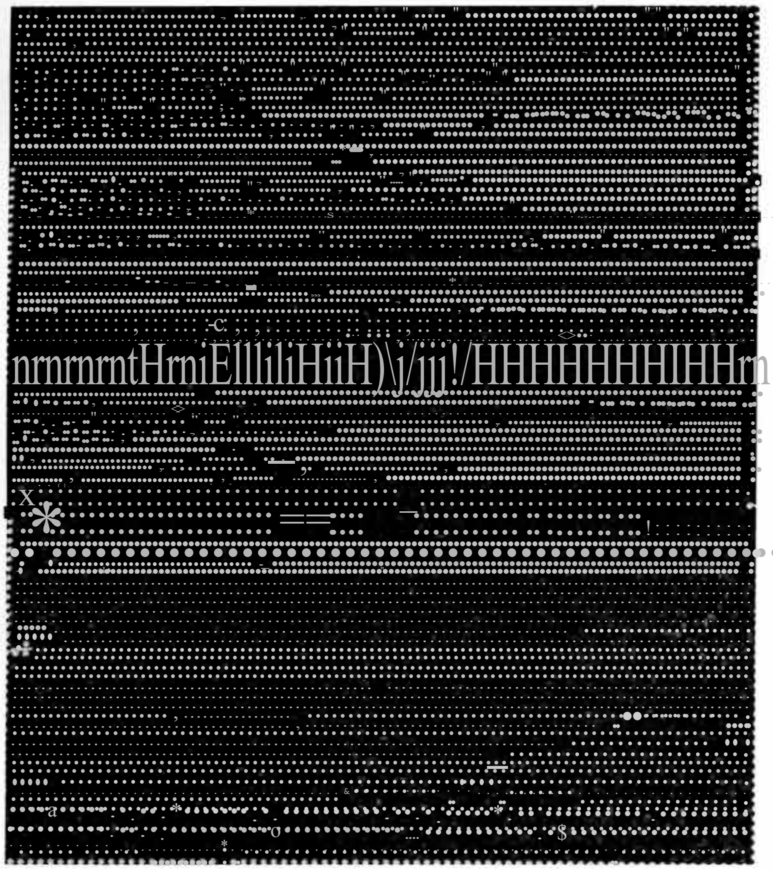

Fig. 10. Enlarged detail (10x) of Talbot contact screen-a blackened film grid with clear circular openings. Smithsonian collection.

into the scorings to create the appropriate opaque lines); (5) waxed paper sheet with lines scribed into the coating and a blacking rubbed into these depressions, (6) an aquatint ground printed on paper which was then waxed for improved translucency (Fig. 9); and, (7) a blackened film grid containing evenly spaced, clear circular areas (Fig. 10).

As part of his search for contact screen materials to divide the image into a greater number of elements, Talbot, in 1854, wrote to a French fabric manufacturer who informed him that fabrics, finer than 150 threads to the inch (22,500 openings per square inch) probably could be made. Talbot evidently did not reveal the purpose behind his inquiry because the manufacturer informed Talbot that, as far as he knew, fabrics of such fine construction would serve no practical purpose. The manufacturer suggested that, if a fine mesh was desired, the type of fabric used for sifting flour would be most suitable because, in addition to fineness of weave, it was very strong and impossible to unravel. He indicated, however, that it might be possible to furnish fabric which has 42,400 openings per square inch. [11]

Talbot was obviously dissatisfied with the gauze-screen techniques described in his 1852 patent. In a letter published in J853 he stated that "two thicknesses of ... gauze is but a rude attempt at a photographic veil ... it would be proper to fabricate a much finer material, and to employ five or six thicknesses ... or ... to cover a sheet of glass ... with ... innumerable ... fine lines, or else with dots and specks, which must be opake and distinct from each other." In this same letter he proposed using an aquatint ground to achieve the same result-a concept covered in his patent of 1858-but was not enthusiastic about such an approach because of the difficulty in applying the ground to each plate.[12]

A fundamental shortcoming of Talbot's 1852 photomechanical system was openly cited by him in a letter published 9 April, 1853.[13] He had found, when producing a photogravure plate, that "the gradations of shadow and the depth of the etching upon the plate do not follow the same law as they do upon the original photograph ... the shadows are too deep and the highlights are too strong." These were problems he was working upon and hoped to solve as "the process shall be better understood." Talbot concentrated on this problem and achieved success within a relatively short period. The corrective approach appeared in his 1858 patent: etching with solutions of different concentrations and using these solutions for selective local etching.

A search through all published descriptions and personal manuscript materials fails to reveal that Talbot ever expressed an awareness about the significance of using a "negative" or what we now call a "working" screen, opaque rectangles separated by clear lines, currently used in the field. A "positive" (master) screen consists of opaque lines on a clear background (Fig. 11), and, in current practice, it is the one from which the "working" screen is produced. Several prints produced by Talbot incorporate a working screen (Figs 12 and 13) but this approach was apprently discarded. Nowhere is there any indication of the methods he used for producing this type of working screen. It is not surprising however, that Talbot achieved such remarkably outstanding results using gauze screens. It will be remembered that he proposed contact printing the screen several times, rotating it between exposures so that each image was formed at a different angle. In practice this approach should have produced a "modified working screen," leaving numerous relatively unexposed areas whereever the lines interesected by superimposition. Exposure balance among the screen images and between the screens and the continuous tone positive must have been fairly critical. Without actually recreating all of Talbot's procedures it is difficult to explain all conditions essential to the success of

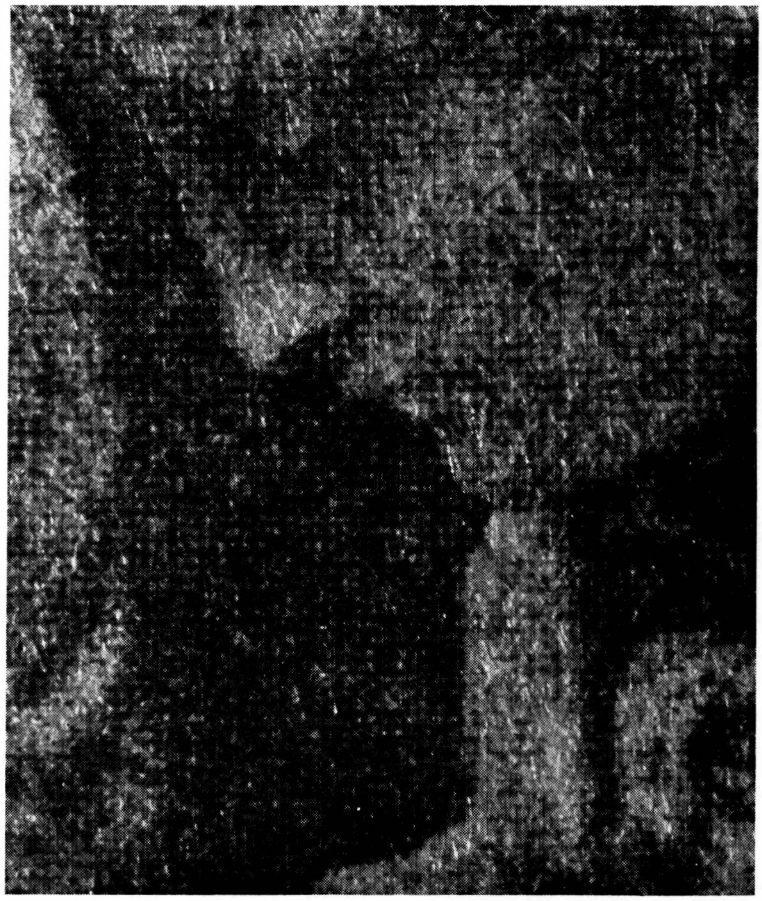

Fig. 11. Enlarged detail (/Ox) of Talbot photogravure print (ca. 1852) employing a single, "master-type" gauze screen, i.e., opaque lines (fibres) separated by the clear areas.

these techniques. The issue becomes clouded even further when one inspects the chronological series of photomechanical prints, containing technical annotations by Talbot. Many prints from this group were apparently made without benefit of any "image dissecting medium" and demonstrate highly commendable tonal quality. The possibility of reconstructing Talbot's technological progress is made more difficult because when prints are pulled the paper fibers tend to spread the ink, obscuring extremely fine detail. More information about this annotated series will be discussed in a later paper on the subject.

Photo-aquatint

Long before photomechanical techniques were introduced printmakers had developed various methods of producing tiny ink holding cells in hand engraved images.14 One of these approaches-the aquatint ground-was adapted to the photomechanical field by Talbot and others. No records exist about the arrangement and equipment actually used by Talbot and his engravers for applying resin to the bichromated surface, but we know that hand engravers of that period applied resin ground in two different forms, as a dust and as a liquid.*

Sometimes the finely powdered resin was tied in a muslin bag and shaken over the plate. Another method consisted of placing the resin at the bottom of a box with the plate suspended horizontally. A bellows then created a dust cloud which settled on the plate. By mildly heating the plate the resin grains were softened just enough to make them adhere to the plate surface.

When etchant was applied it reached the plate through spaces between resin grains, each particle representing a barrier to the solution. It was important for all grains to be the same size so that the final etched pattern would consist of a uniform texture. Etching (biting) had to be done carefully in many stages because the acid not only corroded downward but also sideways, undercutting the resin particles. If undermined too far the walls separating the small cells were destroyed, and large cavities, as noted earlier, lost their ability to retain ink during the wiping stage, thereby ruining the plate.

Talbot, in his patent of 1858, introduced the technique of selective local etching using solutions of different concentration to control the extent of the etch more accurately. At this time he also introduced the principle of laying an aquatint ground on a bichromated gelatin emulsion, a technique which enhanced control of the middle and dark tones of the image. His technique of selective local etching using solutions of different concentration enabled him to control the extent of the etch with highly improved accuracy.

The application of an aquatint ground directly onto the bare metal plate before emulsion coating was described by Talbot in his patent of 1_852. This approach was modified in May 1853 and incorporated into the heliogravure process devised by Claude Felix Abel Niepce de Saint-Victor (cousin of J. N. Niepce) and Augustin Franc;:ois Lemaitre. Their technique called for resin dusting the partially etched heliograph plate which was then mildly heated to soften the resin particles and adhere them to the surface. The plate was then etched to completion.16

These resin-resist techniques were modified still further by Talbot in 1858 who, after contact printing his subject matter, e.g., a flat object or positive photographic print, for one to several minutes, dusted onto the emulsion a small amount of finely-powdered copal. The plate was then mildly heated to

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•A liQuid ground could be made by dissolving *5* ounces of a natural resinous gum. such as copal or guaiacum, in a pint of spirits of wine. i.e.. alcohol. This served as a stock solution which was then mixed 1 part stock to 2 parts of alcohol-the stronger the resin concentration the larger the final particle size.16 Guaiacum is a resinous exudate from tropical trees and shrubs of the family Zygophyllaceae.

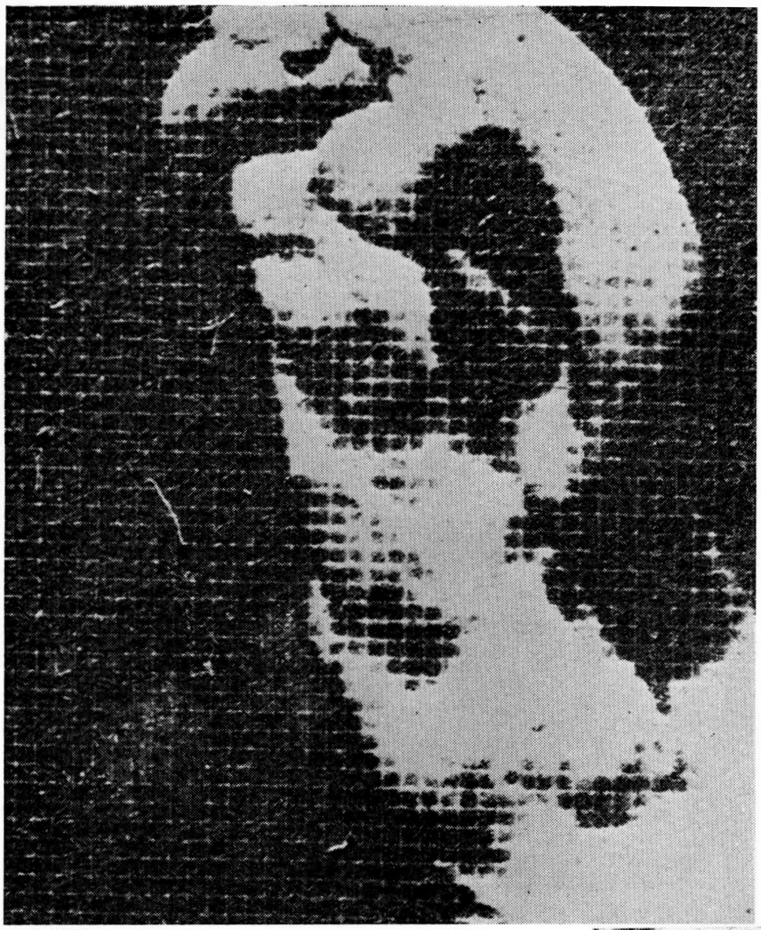

Fig. 12. Enlarged detail **(10x)** *of Talbot photogravure print* **(ca. 1852)** *employing a "working-type" contact screen which consisted of opaque rectangles separated by clear lines, similar to screens currently used in the field.*

Fig. 13. Enlarged detail **(10x)** *of Talbat photogravure screen (ca.* **1852)** *incorporating a double "working-type" screen.*

Fig. 14. Enlarged detail (10x) of Talbot photogravure print illustrating powdered resin aquatint pattern.
Burnett Brown collection.

Fig. 15. Enlarged detail (10x) of Talbot photogravure print illustrating powdered resin aquatint pattern.
Burnett Brown collection.

soften the resin and adhere it to the plate (Figs 14 and J5).

Talbot later improved his technique of applying the resin ground as a liquid (aquatint) by dissolving resin and camphor in chloroform which was poured onto the exposed plate. The chloroform rapidly evaporated as did the camphor when the plate was heated; the resin remained in a well distributed pattern.17 (Fig. 16).

The early history of photogravure of course would be incomplete without a description of contributions by Paul Pretsch, and Karl Klitsch (Klic) of Vienna, C.F.A. Niepce de Saint-Victor, Charles Negre of France and others. These will be covered in a subsequent paper on the subject.

Printing

At least as early as March 1860 Talbot used the services of W. Banks & Son, engraving and printing firm in Edinburgh, Scotland to produce his photoengravings. Mr. Banks often discussed with Talbot routine practices followed in the print shop which might improve Talbot's photomechanical technique. In response to written instructions from Talbot, Banks also experimented with various approaches and would proffer suggested improvements as he thought of them. Even though Talbot could arrange to be with Banks only on rare occasions, the close working relationship pursued through correspondence undoubtedly helped resolve some of the problems encountered with the process.18

Banks, in March 1860, pointed out to Talbot that he should allow a margin of at least one inch around the image area of the engraved plate so that the plate surface could be rapidly wiped clean of ink without accidentally removing any image ink.

One of the first plates sent by Talbot to Banks was rejected by the engraver as being "of the softest sort, and very bad in quality." Banks suggested that the best steel to use for photo-engravings was obtained in Sheffield. It could be converted in Edinburgh, by "one house in particular," into printing plates for the finer class of work. These plates, Banks pointed out, were tempered to suit the type of work.

One of the great advantages of steel over copper was the improved durability for longer printing runs. Banks constantly searched on behalf of Talbot for improved materials; in April 1860 Talbot authorized Banks to order specially prepared steel plates; at least as early as January 1861, they tried using case-hardened plates.

Talbot estimated, in 1860, that he had invested at least £8,000-£9,000 on his photographic inventions (including presumably his photomechanical investigations).19

Supplies, equipment and services used by Talbot were varied. Some typical costs incurred in his photomechanical work are as follows:

1861 - in a bill from David & John Greig, Edinburgh

1 doz. copper plates	5 x 4	13s.
1 doz. copper plates	4 x 3	8s.
2 doz. steel plates	5 X 4	£3

Note that steel plates were 4½ times as expensive as copper plates. Because of their high cost these plates were not discarded after use, but were polished and reused as illustrated by a bill Talbot received in 1861.20

repolishing 3 copper plates	4 x 5	ls. 8d.
repolishing 1 steel plate	4 x 5	ls. 3d.

The paper used for pulling prints was selected by Banks who obtained it from Messrs. Dickenson in London. It was usually in short supply and Banks had to order it weeks in advance to get the sizes and thicknesses he wanted. Banks billed (5 April, 1862) Talbot a price of 5 shillings for the cost of paper and printing 6 proofs from "large" plates.21

Upon the recommendation of Banks, Talbot bought in January 1862, a 13-inch copperplate printing press, from David & John Greig, for £11; and blankets (one in January, one in February and one in March) at 6s. 9d. each. 22

Inspection of photomechanical prints produced by Talbot prior to his 1858 patent reveal a generally good tonal quality. Many of these prints are noted by Talbot as experiments, but the majority of them show highly commendable results. Not until after his patent of 1858, however, did he permit others to publicize his achievements in this area (Fig. 17).

The experimental approaches used by Talbot (to be discussed in a subsequent paper) indicate that he was a perfectionist. Only when his technique was capable of producing reasonably reproducible results in long "runs" did Talbot feel that he wanted to publicly demonstrate the advantages of his process. This approach, combined with the enthsiastic, sympathetic co-operation of William Crookes, editor of The Photographic News, led to the publication of Talbot's photogravure prints in the 24 November, 1858 issue of that journal. The copies each contained one print by Talbot with seven different subjects being used in the run because, according to the editor, (I) production could be hastened by printing from several different plates at the same time (2) they could illustrate "the extent and variety of this new branch of art" and (3) they could include the highest quality prints because "when many thousands of copies are printed from the same plate, it gradually wears out, the last thousand prints being less sharp and delicate than the first." Thus only the first part of the run from the plates was presented to the readers. This approach also offered sales appeal for the publication because the readers also were encouraged to obtain the different prints by purchasing additional copies containing the subjects they desired.23

CURRENT TECHNOLOGY

Emulsion Response

The controls and conveniences provided by modern techniques and commercially prepared products serve to emphasize the extraordinary results achieved by Talbot, who coated his plates with an emulsion made by adding¼ ounce of "household-quality" gelatin to 8-10 ounces of water, plus one ounce saturated solution of potassium bichromate (with ammonia to deacidify), His accomplishments are all the more remarkable if he actually followed his own recommendations proposed in the 1858 patent, such as storing this mixture up to several months in a dark place, melting it by warming before use if it happened to harden in the winter, and varying the proportions "without injuring the result."

Technological insight into the response characteristics of bichromated gelatin, etchants and metal plates was gained only at a much later period. For example, it is now known that bichromated gelatin placed on a copper plate will harden in a region directly against the copper surface, thus retarding penetration by the etchant.24 This condition probably varied the plate response to the etchant, depending upon the time elapsed between coating and etching operations.

After exposure and before development the emulsion proceeds to establish equilibrium between the hardened and unhardened regions. This ***continuing action*** is most rapid within the first hour after exposure and ceases after four hours.25

It also is known that gelatin mixed with potassium bichromate (dichromate) which is permitted to solidify, undergoes slow chemical changes which affect speed and gelatin hardness. These reactions even occur in the dark and the phenomenon has been named the "dark effect". The "dried" emulsion proceeds to harden so that less exposure is needed to produce the final image hardening.26 When emulsion is stored in solution form however, there is an opposite effect on hardening.27 If Talbot (and others) relied upon stock solutions prepared in advance and stored under varying conditions for varying times, sometimes using remelted emulsion, he

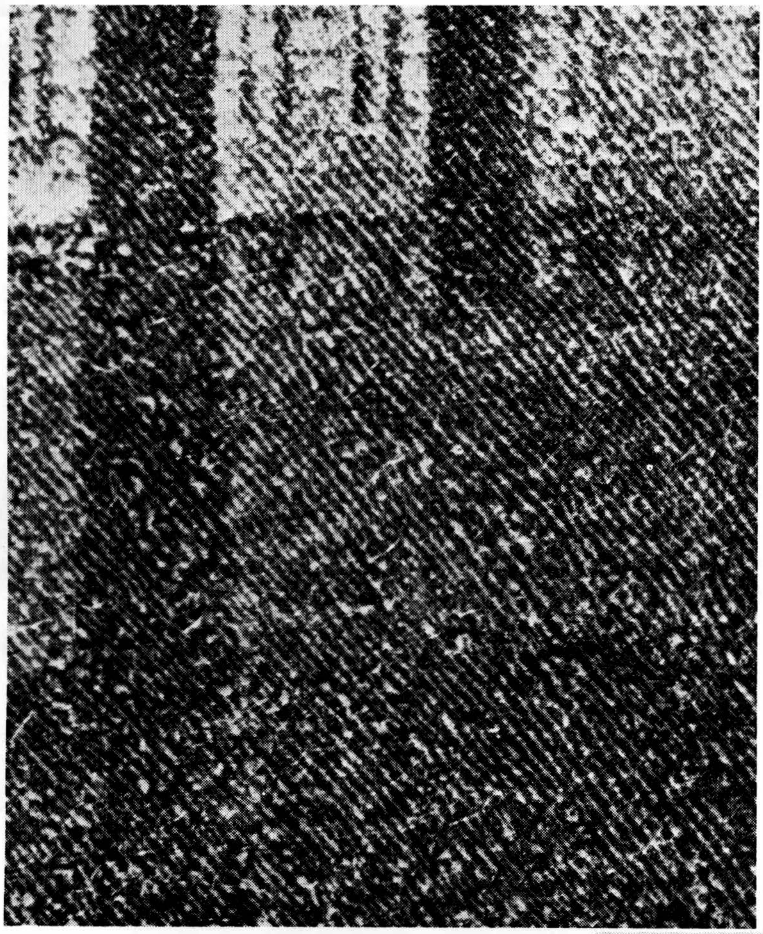

Fig. 16. Enlarged detail (10x) of Talbot photogravure print illustrating pattern left by liquid aquatint ground. Aquatint solution was made by dissolving resin and camphor in chloroform

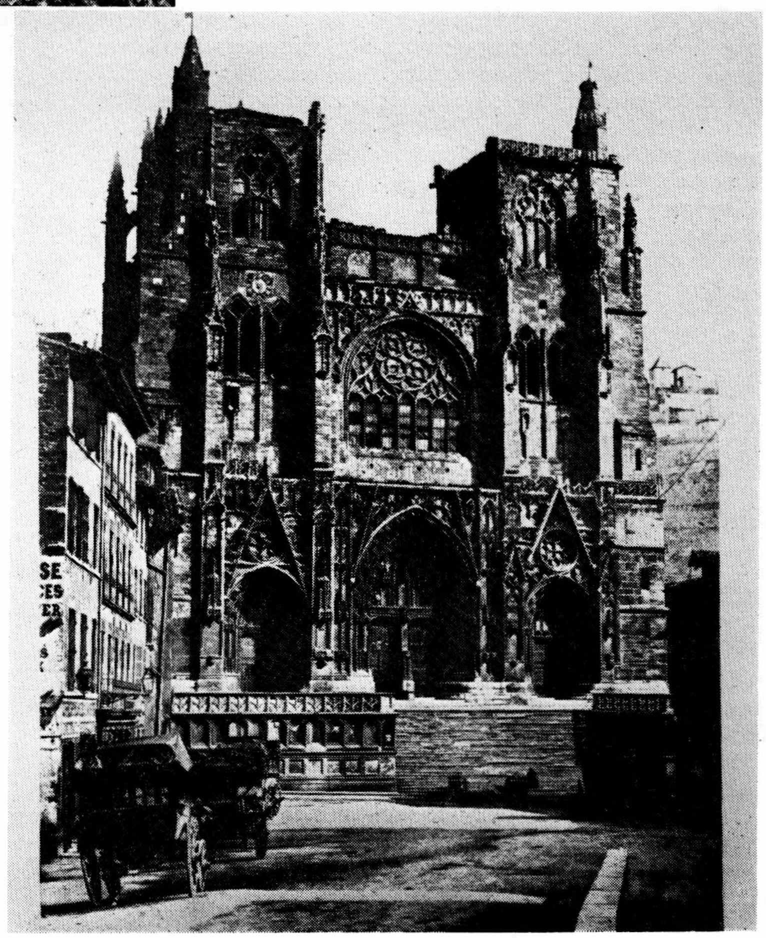

Fig. 17. Photogravure print by Talbot **(1866),** *Church of St. Maurice, Vienne, France.*
Burnett Brown collection.

could not have avoided the presence of ever-shifting emulsion response. It is possible, of course, that Talbot did not follow his published recommendations and used only freshly prepared emulsion each time, but included this reference in the patent to round out his legal protection.

Carbon Tissue

Bichromated gelatin when first exposed to light becomes insoluble and hardens near the surface; increased exposure causes hardening deeper into the emulsion.[28] This characteristic is now used to good advantage in current photomechanical practice.

Instead of handling the cumbersome emulsion-coated metal plate throughout production, the engraver makes two exposures, onto a carbon tissue, a gelatin emulsion containing pigments, plasticizers, preservatives, etc., coated on a paper base. The tissue, sensitized with potassium bichromate shortly before exposure can be stored up to about six weeks with refrigeration. Following exposure the carbon tissue is combined, emulsion side down, with a wetted metal plate in a stage called "laydown".

Exposures are carefully adjusted so that the emulsion is not hardened throughout its thickness, remaining unaffected (unhardened) in the region closest to the paper base. Then an application of hot water soaks through the paper, softens the underlying gelatin, and permits easy removal of the paper. Additional washing in hot water (a step called development) removes all unexposed, unhardened emulsion. What remains is a hardened, gelatin relief image, its configurations corresponding to the amount of light received during exposure to the screen superimposed over a continuous-tone image; the gelatin being thickest in regions of maximum exposure.

Generally, carbon tissue is sensitized by soaking it from four to five minutes in about a 3½% solution of potassium dichromate, at pH 6.0, liquid ammonia being used to adjust from a lower pH. A temperature anywhere between 40°-70°F may be used, but those approximating room conditions are usually established as the working standard. Every effort is made to maintain the selected temperature at a constant level.[29]

The swelling characteristics for gelatin in a dichromate solution are about the same as in plain water.

In order to accommodate the greatest possible variety of working conditions and copy material as well as process modifications, carbon tissues now are made available in various contrasts, speeds, and physical harnesses.

Controlled Etching

Etching still is done with ferric chloride-an approach which is generally the same as Talbot introduced in 1858. Solutions of different concentrations are used and the most concentrated one is applied first. It penetrates only the thinnest emulsion areas, those corresponding to shadows. Progressively weaker solutions are applied, each penetrating thicker emulsion areas, i.e., those corresponding to lighter tones. Whereas Talbot used only three different solutions, anywhere from four to six are now used, the entire procedure taking somewhat less than 25 minutes.

The etching action of a given concentration of ferric chloride solution on copper is uniform and the depth to which it affects the plate is a function of time.JO When ferric chloride is applied to the plate the gelatin swells to a maximum and the solution diffuses through the emulsion to etch the copper. The emulsion swells rapidly at first, in about three to four minutes, but the rate decreases as the maximum is reached in about 20 minutes or more. It is thought that the diffusion of etchant through the emulsion does not start until after maximum swelling is reached.[31]

With more concentrated ferric chloride solutions emulsions swelling occurs at a slower rate. This swelling-diffusion arrangement is completed more rapidly with thinner gelatin layers, thus plate regions underlying thin emulsion areas begin to etch first, followed at longer intervals by etching of regions underlying thicker layers.[32]

Weaker ferric chloride solutions are absorbed more rapidly by gelatin. A solution concentration can be selected so that it will penetrate thinner layers, i.e., areas corresponding to dark tones, while failing to penetrate thicker layers.

Relatively recent investigations have led to control of ferric chloride etching characteristics by adjusting the level of free acid. The addition of hydrochloric acid for example, increases penetration rate, improves the depth of bite, and results in a finer grain on a bright copper surface. The addition of ferric hydroxide decreases penetration rate, reduces depth of bite and results in a somewhat darker copper surface.[33]

The rate of solution penetration is affected by the emulsion moisture content. Equilibrium of the resist with surrounding relative humidity is established in about two hours and it therefore becomes important to control both room temperature and relative humidity. After development the emulsion should be unformly dried because etching solutions more quickly penetrate areas which are dried slowly than those which are dried quickly.[34]

Penetration of the emulsion is affected by temperature and the practicable working range is about 64·-72 °F in operation, a fairly narrow limit of about ±2· is used.

The penetration rate also is affected by the solution already contained in the emulsion. It has been found however that throughout the Baume range normally used,* etching rate remains the same, as measured from the time it starts affecting the metal plate.[35]

To help mitigate variable responses from these sources it is now common practice to pre-condition the emulsion in a ferric chloride solution which is just a bit too concentrated to penetrate the emulsion, i.e., about 43 °Be. Solution concentrations are now designated in "degrees Baume (Be)" and the useful limits in photogravure lie within the fairly narrow range of about 35°Be-42 °Be.

Screens

The cross-line gravure screen currently used consists of opaque rectangles with clear lines. This "working" screen, usually on photographic film, is produced by contact printing from a "master" glass-screen containing opqaue lines on a clear ground. The exposure sequence through the positive transparency and the screen can be varied without affecting results.

Master screens are available containing from 3,600 to 9,000 cells to a square inch (rulings of 120, J33, 150, 166, 175, 200 and 300 lines per inch). This ratio of ruled line to cell ranges anywhere 1:2 to 1:3½. The screen configuration is selected to suit the type of work being done.

Image tone is controlled by the depth and area of the cell and by the ratio of land to cell areas, i.e., non-printing to printing area. The land widths, however, remain the same for any particular image but this can be varied from one subject to another. The lands, in addition to dividing the image into a larger number of ink-holding components, provide an essential adjunct to the high-speed ink wiping arrangement practicable through the use of a doctor blade.

Many approaches have been devised using different screen configurations which depart from the "conventional" approach to photogravure. For a detailed explanation of

•Baume (abbrev. BC) . . . an arbitrary scale of specific gravities devised by the French chemist Antoine Baume and used by him in the graduation of hydrometers- The relations to specific gravity (at 60/60°F) are:

°BC= 145•145/sp. gr. for materials heavier 1han water

°se = 145/sp. gr.-130 for materials lighter than water

The Condensed Chemical Dictionary; Reinhold Publication Corporation, New York, 6th edition 1961.

many of these techniques, appropriate references are included in the bibliography.36

Mass Production

Printers during the earliest practice of the art, inked the photogravure plate and then wiped off the surface ink with a cloth and hand, taking extreme care not to remove ink from the cells-an approach borrowed from prior practices followed when prints were made entirely by hand. Slightly dampened paper was then squeezed in contact with the plate, under great pressure, and the ink contained in the cells transferred to the paper. The practice of hand-wiping ink, as might be imagined, seriously restricted production output.

The doctor blade, used in 1785 in England for textile printing,37 was ready and waiting to provide the automated wiping arrangements essential to high speed production techniques in photogravure. The function of this device, a long, thin steel blade which rides along the surface of the plate lands, is to squeeze off surface ink. This method enabled photogravure to be adapted to high speed rotary printing techniques. In practice, cell area has an upper limit, beyond which the doctor blade will lift out the ink and damage the tones.

The descriptions set forth here are greatly abbreviated. Photogravure practice has expanded to include the use of cylindrical shaped printing plates which are ideally suited for high speed runs. Sheet fed gravure presses (rotary), which in the U.S. can accommodate sheets up to 29 in. x 43 in., operate at about **3,000-6,000** images (on one side of the paper) per hour depending on the work being done. High speed rotogravure presses have been built which can print *15* million catalogue pages an hour.

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(20) ***Ibid.***
(21) ***Ibid.***
(22) ***Ibid.***
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2. Congress of Deputies, Madrid
3. Court in the Alhambra, Granada
4. Palace of the Due de Montpensier, Seville
5. The New Louvre, Paris
6. The Gate of the Cathedral of San Gregorio, Valladolid
7. The Institute of France
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