

THE PRODUCTION OF PERMANENT PLASTIC SCALES-I

PHOTO-IMPREGNATION OF COMPLICATED AND PRECISE SCALE PATTERN ON 'PERSPEX'

by

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ABSTRACT

This paper deals with the production of 'Perspex' protractors where the image pattern becomes integral with the base by a process based on photo-impregnation principle. This process involves building up of an impervious photographic stencil in a resistant material usually termed a "Resist" (a coating that protects the area it covers from chemical action) on the "perspex" surface followed by chemical attack on the exposed portions of the plastic through the unmasked areas of the stencil with a tinted solution of an adequate solvent preparation. The image is rendered visible by the combined softening, penetrating and staining effects initiated by the etching cum dyeing mordant on the base. In course of the treatment the dye gets entrapped and deeply embedded into the material of the base. The tender dyed characters are allowed to harden and set by the evaporation of the solvents. The composition and action of the dye incorporating medium is so governed that it does not chisel by forming image wise cavities due to removal of material from the "perspex" as is usually associated with all commercial photo-mechanical etching processes.

Introduction

The 'Photographic Technology' Department attached to the Optics Division of Ordnance Factory, Dehra Dun was in recent past called upon to explore the possibilities of making a few "perspex" protractors in preference to celluloid protractors, the manufacturing technique by photo-mechanical means of which has already been invented by author and to develop a technique for their production with a particular emphasis on a photo-mechanical means of reproduction that would facilitate quantity production. Photo-chemically calibrated "perspex" protractors do not appear to be available commercially in this soil and we had no experience of such a technique capable of ensuring permanent markings on acrylic base. Further more no reference in literature could be traceable relating to this specialised problem.

Preliminary Investigations

To be precise to the exacting requirements befitting a solution to the problem, no light sensitive coating was at our beck and call that, under suitable

exposure and development, would form the required mask or resist, that would also withstand the action of etching mordant used to photo-impregnate the pattern into the "perspex". A number of photo-mechanical enamels/resists were tried and all had to be finally discarded for their failures to yield favourable response. The coatings would invariably crack, undercut, decompose or become permeable to the powerful solvents and penetrating action of the etchants at different stages. Thus the current and standard types of anti-corrosive enamels formed of fish glue or albumen universally and adequately adopted in photolithography and metal engraving industries could not be profitably utilised for this novel problem as both broke down in alcoholic phenol hereafter commissioned for etching "perspex". Other natural colloids such as gelatine and gum arabic from different sources or even different lots from the same source are often said to possess marked differences in their photographic properties. Our experience with a few consignments of this material has led us to believe that further reinforcements of the colloid may be required to satisfy the requisite conditions for uniformly fruitful application and reproduction for this work. The programme of research was, therefore, continued further and during the concluding phases of trials prior to achieving success cellulose lacquers, asphaltum, shellac, resin preparations were tried without any tangible results and had to be finally abandoned. At last it proved to be indeed a lucky choice to detect that the real answer to the problem was latent in a 'proprietary' product-Astrafoil coating Powder-marketed by South Wales Chemical Works Ltd., Surrey. Thus it was possible to transform Astrafoil Coating Powder to a so called Perspex Coating Powder so smoothly and easily since the photochemical functioning of the powder when suitably applied as a resist on 'perspex' appeared to be of optimum characteristics in all respects. It was also soon realised that the product was not a presensitized photo-resist containing any light sensitive catalyst nor did it constitute the undercoat of a double layer process so that the entire technique was standardised by employing a light sensitive layer of a bichromated Astrafoil Coating Powder of a suitable composition. It was subsequently revealed that this sensitive layer was not rendered completely insoluble by light, it only became less soluble and in keeping with this behaviour it was reasoned that it might be possible to repeat the developing technique effectively in this case also by following the procedure adopted for production of photo-litho offset plates by the so called reversal process in which the image is developed in a light fixed bichromated colloid layer by means of a high concentrated acidified salt solution instead of being developed with water. This reasoning was proved to be well conceived and it was a triumph to trace out a substitute of known composition which could so far successfully replace the trade developer offered by the maker of the powder for working on Astrafoil.

Salient Features

This process is capable of ensuring stable photographic reproductions of superb quality formed on "Perspex" for production of scales, dials, diagrams, charts, announcements, nameplates, complicated designs, fine line details, delicate patterns etc. which will remain permanent on storing and will withstand physical abuse. The characters will not bleach or fade and are entirely water and weather-proof. The pattern is neither "proud" on nor recessed into the material and as such it is least susceptible to mechanical damage by sliding

action or amenable to bringing out of the filler from the sunken portions during faulty handling. No deterioration to the marking can be caused while handling for machine profiling and drilling operations and subsequent cleaning up. Excellence of definition, sharpness of contours, uniformity of widths and high resolutions of the characters are the outstanding features of the technique. The details are of uniform and continuous densities and are never spongy in structure. The process is capable of yielding uni or multi-colour and decorative effects on transparent and possibly on opal and coloured ones also. The process holds good for both narrow and wide details and in both cases the permanency of the image is strictly maintained. Formation of protruding elements as caused by engine dividing or by stamping is eliminated in this process. The surface carrying the impression may be polished without any detriment to the pattern to provide an extra gloss to the background. No protective covering is considered necessary to minimise the risks of the calibrations being rubbed off. The contrast of the image is correspondingly high.

Single-Layer Photo-Impregnation process—Direct contact method

The working details of the reproduction process are described below: The procedure consists of the following ten stages:—

- (1) Preparation of photographic "Master"
- (2) Making up of processing solutions (light sensitive emulsion, developing and etching fluid)
- (3) Preparation of the "Perspex" surface
- (4) Sensitising the prepared surface with photosensitive coating of Astrafoil Powder
- (5) Exposure and Exposing lamps
- (6) Developing Stencil Image
- (7) Spotting
- (8) Etching and Dyeing up
- (9) Stripping down the mask resist and stabilising the pattern
- (10) Cleaning up and Repairing flaws.

Preparation of Master Positive Transparency

The production of protractors require the preparation and use of master positive for contact exposing. Negatives photographically reproduced to the exact working (1 : 1) dimensions by reduction copying from an accurate and enlarged master chart representing the pattern by using conventional photograph—measure—adjust method with the aid of a photoengraver's camera are employed for evolving the required master positives necessary for contact photo copying on "perspex" blanks suitably sensitised for further processing. In taking photograph, residual aberration of the camera lens or vibrations during exposure will obviously tend to impair the hardness of the edges of the markings in the image. It is necessary, therefore, not only to ensure that the camera is rigid but also to find the best photographic as distinct from the vest visual, focus. The lens should be used at the aperture which is found by trial to give images showing hard and sharp edges and no distortion due to spherical aberration when examined under a magnification corresponding to that under which

the finished job will be used. The opaque parts of the positive must be really opaque and the open parts should be clean and free from scum and tint.

Making up of Sensitive Emulsion

This is the bichromated Astrafoil solution. The coating solution is made up by dispersing 250 gms of Astrafoil Coating Powder in 1000 c.c. of distilled water. To 1000 ccs of this solution are added 300 ccs of 25 percent Ammon. Dichromate to which had been added 10 ccs of liquid ammonia 0.880. The powder should be soaked overnight in water so as to facilitate homogeneous blending of the mixture. Absence of particles in the sensitising solution is achieved by careful filtration through absorbent cotton somewhat compressed. The filtrate is allowed to stand for at least 24 hours for maturing before use. It shows remarkable keeping qualities and should be preserved under subdued light in well corked deep coloured bottle preferably in a cool atmosphere.

Films made from aqueous solution by evaporation have easy working characteristics and the stencils worked out are tough, non-porous, adherent, flexible and unaffected by many solvents inclusive of powerful ones like carbolic acid and offer considerable latitude during processing.

Principle underlying the Process

The basis of the process lies in the action of light on bichromated colloids. The Astrafoil Coating, a colloidal preparation, is rendered sensitive to light by incorporation of ammon di-chromate and this is held in suspension by an aqueous solution of Astrafoil Powder the latter being rendered insoluble when exposed to the influence of actinic light. Differences of solubility and permeability between the parts exposed to light and those protected from its action may be utilised for photo-mechanical stencil making as a means to an end. When the bichromated emulsion dries to a skin it becomes sensitive to light and the sensitised panel is next manipulated in the non-actinic light until it is exposed and developed. If unduly prolonged period passes away between coating and development the job becomes useless even if preserved in the dark. This deterioration is the inevitable outcome of the hardening of the film taking place slowly even when kept away from light. Light usually excites and hastens the chemical change that is already proceeding. This change amounts to splitting up of the bichromate into a chromic compound with liberation of oxygen which acts upon the colloidal product. The chromic compound unites with the unaltered bichromate to make an insoluble chromic chromate. Finally the image composition carries an insoluble chromic chromate colloiddally dispersed in oxidised ingredients of the vehicle. A condition of insolubility is reached whether light acts on the coating or not. Light simply promotes the speed of reaction.

Preparation of the "Perspex" Surface

The "perspex" sheet is cut to the size required, usually allowing $\frac{1}{2}$ in. around the actual limits of the image to allow for handling during the various operations which follow. The surface prior to processing must be completely free from contaminant films such as grease, dust, particles of gelatine adhesive etc. It is a best course to clean the sheets with warm, soapy water, wipe it with soft rag, rinse in clean water, dry and polish with a clean soft cloth. Dirts of an oily

or greasy nature may be removed by using hexane or naphtha on a soft cotton pad. The most suitable face reasonably free from objectionable scratches is selected for undergoing sensitising since during etching the acid fluid tends to run along the appreciably deeper scratches thereby contributing to the staining of such portions.

Sensitising the prepared side with the photographically sensitive coating of Astrafoil Coating Powder

The highly polished, water repellent and non-absorbent face grossly behaves as a rebel base to start with for its cold response in accepting the sensitive deposition. Its apparent obstinacy is overcome by sponging the surface, well rinsed in water, very thoroughly in circular motions using a wad of cotton wool soaked in Astrafoil Coating Powder solution. The surface thus treated when washed in water should take water film evenly over its face. For evenly spreading and drying the coating a special whirler is employed consisting of a flat turn table which can be rotated at varying speeds either by hand or power. The blank is mounted in the centre of the spinning table and the prepared top surface is rinsed with water, and the excess is thrown off by spinning so that the surface is left just damp. When stationary, the carefully filtered sensitising solution duly freed from bubbles is applied in a pool in the centre of the blank and is distributed over the entire surface by means of a glass rod or the tip of finger. The whirler is set in motion and left running at the correct rotational speed of 100 R.P.M. until the layer is dry. By centrifugal force the solution is caused to be carried over the surface of the plate. The speed of whirling should remain constant or variation in thickness of the dry coating may very likely occur. The layer may preferably be dried cold so that it is no longer tacky to the finger when felt. Application of heat but of a gentle order may introduce the possibility of accidentally overheating and promoting partial insolubilization of the film before exposure. Distortion of the plastic and rapture of coating cannot be ruled out under the circumstances. It is essential to exclude formation of air bubbles at all stages in the coating and elimination of dust is the paramount requirement for successful work. Streaks, spots and other imperfections are to be avoided to the utmost in the coated layer. One application of coat is generally considered enough provided it is not allowed to be unduly thinned down with water remaining on the plate. The sensitised coating is susceptible to blue and ultra-violet radiations and an orange light is necessary for illumination of coating room against extraneous action of actinic light. On termination of coating, the plate is dislodged from the spinner and which now awaits exposure after wiping off excess solution from the back and edges of the blank.

Exposure and Exposing Lamps

The sensitised blank is exposed behind the line positive in a spring pressure photo-mechanical type of printing frame for a time which will be influenced by—

- (1) the intensity and spectral energy distribution of the printing light and its distance from the frame,
- (2) the composition and condition of the solution,
- (3) the relative humidity of the atmosphere in the department,
- (4) the sensitivity and thickness of coating,

- (5) the type and general density of the master,
- (6) the character of the image and the result desired in the long run.

The exposure time is best ascertained by trial. A 400 W 230 V Siemens Mercury Vapour electric discharge lamp provided with a reflector placed at about one foot above the frame was used as the illuminant and the duration of exposure was about 5 to 8 minutes as the average time. In bright sun light it takes about a minute only. During exposure the sensitised surface of the plastic must be pressed hard against the emulsion side of the "Master" in order that any stray light will not find its way round the back of the lines, thus exposing the wrong portion. Black paper backing should be used to counteract back reflection, if any, of light during exposure. Also the coated plate should not become warm during exposure.

The life of "photo-flood" lamps is short and rather uncertain as the brilliance is obtained by "over-running". Photo floods should only be used where initial coat is the most important factor because the running costs, including replacement of bulbs, works out quite high, Mercury vapour lamps represent an economical means of exposure where A.C. current is available and the 250 watt or 400 watt lamps are most popular.

Developing Stencil Image

The image is not developed in the usual manner by rinsing in cold plain water since the entire coating inclusive of the exposed areas will break down in no time in such an attempt. Whereas an acidified (lactic acid) concentrated aqueous solution of Calcium Chloride will dissolve the unexposed portions smoothly without having detrimental effects on exposed areas. The developing solution recommended for use has the following constitution. The operation has to be conducted in non-actinic light. The manipulation and progress of the operation should be closely studied and controlled for successful work.

Developer :

Saturated aqueous solution of Calcium Chloride 10 Oz.

(40° Beaumé) Lactic Acid 1/2 Oz.

A small quantity of this solution is poured on to the centre of the plate, which is laid flat face up on a white surface and is immediately and uniformly distributed over the entire job area with a pad of clean and dry cotton wool. The mixture is kept in constant motion by gently rubbing with the pad which is renewed frequently. Very soon the unexposed portions start to dissolve and the pattern can be recognised standing out clearly against the background. The removing of old developer and replacing with fresh is carried out as required several times to ensure complete elimination of unexposed portions and the surface is absolutely free from traces of dissolved coating. The job is next passed on to the spotting stage if required or directly subjected to dyeing operation.

Spotting

If any portion of the stencil after development requires to be covered up before dyeing up it should be done by treating the developed image with denatured industrial spirit until no colour comes off the plate. Cotton wool swab

in circular motion will assist the operation. On completion, when the surface is dry the flaws are painted out with tinted bichromated coating solution, the colouring matter being added as an aid to visibility. When dry the specimen is ready for etching.

Etching and Dyeing up

The image area is swabbed over exerting uniform and light pressure with a pad of clean and dry cotton wool stuck to one end of a glass rod serving as a handle and duly soaked somewhat lavishly in the following coloured binary solvent mixture:—

Carbolic acid (liquid)	..	..	..	40 c.c.
Denatured Industrial spirit	..	..	..	100 c.c.
Waxolene Dye	..	..	..	10 gm.

This constitutes development of a mild acid fluid whose powerful and caustic solvent action is greatly moderated by the use of the spirit which also maintains all the ingredients in solution. Thus the concentration of tensions in the remaining material around the edges of the characters is lessened during etching and the undesirable unevenness of the details are prevented. Provided the stencil had been correctly developed, in course of colouring the plexi-glass sheet gets readily attacked by the dye solution on a pattern-wise basis reaching up to the maximum tone value shortly. This should be carefully ensured prior to washing away the resist by adjusting the duration of the treatment and closely watching the progressive effects produced at regular intervals with the removal of excess fluid from selective regions. The most important trick is efficient swabbing with the right amount of pressure and at the right rate but not necessarily have to be done the whole time the surface is left open to the action of the fluid. Over-etching, as customary, in any case is to be avoided.

Stripping down the Mask Barrier and Stabilising the Dyed Characters

On termination of dying up when the image is reasonably surface dry the hardened stencil is washed out by placing the sheet in a stream of running water. Loosely adhering portions, if any, may easily be removed without damaging the job by lightly wiping the surface under water with cotton wool. This should be done by judicious application of hand pressure avoiding vigorous scrubbing as the dyed image at this stage is somewhat tender and does not spontaneously dry out completely and any drastic treatment is likely to cause a tenacious smear to be built up round the edges of details and at unprinted regions of the stencil. The printed surface is next blown dry and left freely exposed to moving air at room conditions of temperature and humidity until the characters are thoroughly dry. The use of a forced draught speeds up drying only to a very small extent. The limiting factor is not the speed of evaporation from the image areas, amenable to forced draughts, but the rate of diffusion of the solvent through the image film-unaffected by draughts.

Cleaning up and Repairing Flaws

The operation subsequent to removal of stencil is to clean up the background of the pattern so as to render the same, free from all unwanted dark/

coloured specks, stains, smears, or any other surface blemishes which might have resulted in chiefly arising from dust, foreign particles etc. and escaped during previous stages. The use of benzene or allied solvents for application on the base as a general purpose cleaning medium or as a local cleansing agent designed for any specific requirements appears to be untenable in that the surfaces wetted by such a solvent may lead to wide spread surface crazing of the material being affected somewhat briskly as such. Even their vapours are said to be able to act adversely in this respect causing such harmful manifestations if the jobs are left exposed unduly to their influence. It is opined that employment of such solvents under normal workshop conditions will hardly leave room for sufficient technical control over the generation of the erratic features or its total elimination when placed at the disposal of general operatives neither conscious of nor accustomed to work calling for stringent laboratory controls. Stray spots, scums etc. if any can easily be cleaned off by the aid of chisels made of ivory sticks or properly mended ends of peg woods suitably dipped in alcohol by careful manipulation of local and selective treatments involved in the operation. Cleaning and polishing of surface or parts thereof can even be more effectively resorted to by the use of "Perspex" polish No 1 and No 2 marketed by I.C.I. as per instructions laid down in their literature on their use. These should be in short, applied very sparingly on the surface so that the pattern survives the treatment fully and justifies the claims involved.

Discussion

Attempts are in progress to evolve indigenous substitute for proprietary material, Astrafoil Coating Powder. The author has got a strong feeling that the resist used in the process is a plastic resist with particular reference to the P.V.A. family or a properly reinforced natural colloid resist of fixed composition and has already initiated action to identify the same. In standardising and implementing the process the snags which can be seen in the operation of a process under usual workshop conditions which are vastly different to laboratory conditions were kept uppermost in the mind and due consideration was attached to this most relevant production aspect of the whole affair.

While establishing the process in our workshop endeavour has been successfully made to produce satisfactory results under a very wide and elastic range of temperature and humidity conditions as observed at the atmospheric conditions inside the room of laboratory/workshop particularly in the tropical countries like that of ours, as such the difficulties associated with maintaining critical conditions of temperature and humidity for conducting usual chemical processes have been completely eliminated.

Another requirement was that, so far as possible, the methods worked out and used should be capable of rapid assimilation by operatives with limited previous scientific or technical training.

The technique possesses the potential reserves of producing slide rules radio and automobile dials, drafting triangles conversion tables and allied job on the acrylic base. On account of contact photographic reproduction involved in processing the distortions and other variations in the marking of scales are ruled out.

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