Mapping the Hard Way

Doug Rose – May 2015

Introduction

Though the origins of computer generated graphics date from much earlier, they started becoming a practical reality in the late 1980s. With this now the norm and even making those early days seem primitive, this article looks at some of the ‘photo-mechanical’ working practices that were the norm beforehand.

The reproduction of ‘half-tones’ (comprising continuously variable shades of single or multiple colours as in photographs) has much in common with layer tints (where the shades remain constant over small or large areas and also called ‘continuous tone’), this piece however will only deal with the latter.

Though there were and are many ways of printing, ‘letterpress’ and ‘offset lithography’ accounted for the majority of general-purpose publication printing during the 20th century, with lithography (litho) dominating to an increasingly high degree with time. Indeed, letterpress was almost not used for anything larger or more complex than business cards by the 1990s.

As with any well planned exercise that involves many stages, the most efficient methods are those which make the following ones as easy to fulfil as is practical. In order to understand why things were done the way they were, it is therefore better to look at the processes involved, working backwards from the printing press, only then will I explain how the work was originated. The production example I will be citing, that of London’s Underground diagram, has been printed lithographically for many decades now, and in numerous forms. As with many technical procedures, there is more than one way of achieving the same result. What I am about to describe was pretty standard, though different jobs would have been tackled by variations on a theme, depending on the draughtsman’s preferences.

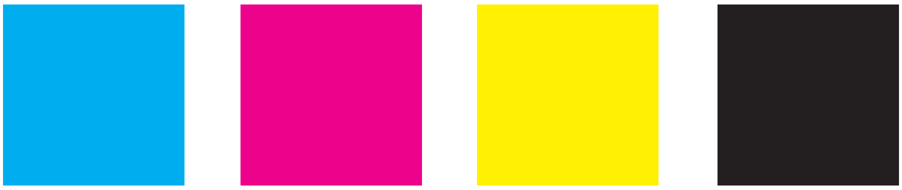
The Basics of Offset Litho Multi-Colour Printing

A litho printing press works by transferring the required image from a printing plate (a thin sheet of metal wrapped round a large rotating cylinder) onto a rubber-like ‘blanket’ wrapped round a second rotating cylinder and in turn (hence ‘offset’) onto the paper which passes its surface. The colour that emerges is the result of the choice of colour ink applied to the plate, via rollers, at the time. This is irrespective of how the original artwork used to be produced and just as relevant for printing from today’s computer generated equivalents.

The Underground Diagram depicts the various individual railway routes in coloured lines specific to each. Hence the District Line is green, the Central Line red and so on. If money (and time) were no object, the best result would be achieved by printing each of these colours, using inks of the appropriate colours, one for each line. It can be seen that this would require the use of around ten colours (and plates). If done this way, the process would be similar in concept to buying several different colours of paint and painting ten different walls each from one of the tins.

Printing presses can be made to print several colours at once simply by building them as a series of plate and blanket cylinders in a straight line. The cost of building anything more than a 6-colour press is colossal. Its physical size is also very large to house and the operation complex to control. There would be one other not inconsiderableable problem – how to keep all the plates imparting ink in precisely the correct place on the paper, so that they fitted perfectly to all the others. This is known as ‘registration’.

It can be seen therefore, for practical purposes, printing numerous individual colours is seldom (if ever) done. The trick for achieving the myriad of colours that manifest themselves on almost all printing jobs is the result of using translucent inks on top of one another. So, by printing blue from one plate and yellow from another, precisely in the same place, we get green. This is accomplished by using the four primary reflective colours: cyan, magenta, yellow and black and is known as ‘4-colour process’. (Your computer screen and television work in the opposite way using transmissive primary colours: red, green and blue, hence RGB.) 4-colour process can produce a great variety of colours and shades and is a clever compromise, but compromise it is and it does have its limitations.

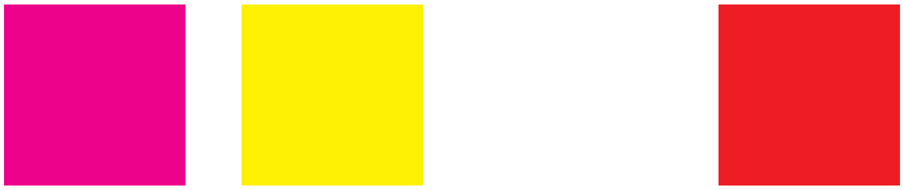


Left to right: solid (100%) cyan, magenta, yellow and black.

It is important to understand what happens when colours are superimposed. In its simplest form, printing cyan with yellow will result in a dark green; printing cyan with magenta will result in a dark purplish blue; magenta with yellow produces a bright red.

Left to right: solid cyan, solid yellow and the two combined (100c/100y).

Left to right: solid cyan, solid magenta and the two combined (100c/100m).



Left to right: solid magenta, solid yellow and combined (100m/100y).

But what if light green is wanted? One answer would be to dilute the ink but this causes other difficulties. If the cyan ink is weakened we could indeed get light green, but then we would also get light mauve when combined with magenta and we might not want that. Therefore there has to be a different way to control 'weakening' of the colour in selected areas, and it is found in the process prior to the printing press being brought into use. Where did that image on the printing plate come from?

In the early days of litho printing, the image was engraved directly onto the plate and there was little room for errors to be rectified. The present computer methodology allows the image to come direct from computer files. In the days before computers the images on the plates were produced by a photographic process, it having been exposed from either a film negative or film positive. Again there are exceptions, but usually it was only practical to make one exposure to the plate, and for reasons that will become apparent farther on, complex images to plate were usually made from positives.

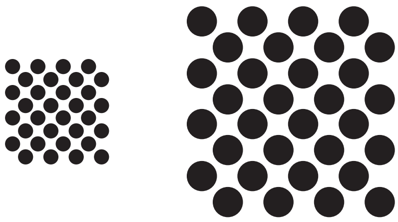
When we view a conventional 'snapshot' photographic print (also now almost completely a thing of the past), we see continuously variable tones from the full spectrum of visual colours. Without wishing to go into the realities of how this is achieved, suffice it to say that litho printing does not work in the same way. It is not possible to print lighter shades of the colour ink being used with predictable results; the colour of ink being applied is usually reproduced to the full strength as it comes out of the tin. (This isn't quite true but explaining why not is beyond the scope of this piece.)

Examine now what a black & white photograph reproduced in a newspaper looks like and one phenomenon immediately becomes obvious – it is made up entirely of dots. Look closely under a magnifying glass and it can be seen that all those dots are the same density of black; there are no light, medium or dark grey ones, nor any shades in between. This particular illusion of a full range of tints is accounted for simply by the varying size of the dots. The bigger the dot the darker the apparent tint. And all achievable simply because the human eye/brain combination is unable to resolve the image in such tiny detail – so we 'see' a picture.

In this enlargement, all dots are clearly solid black.

Because of the poor quality paper and the speed with which newspapers are printed, it is only possible to achieve an acceptable photograph using a fairly coarse density ‘dot screen’. When inspected, newspaper dot screens could be seen to have, typically, 65 dots-to-the-inch, though recently improvements in techniques have pushed this up a little. However, in high quality printing, screens of 150, 175 and even 200 dots per inch are commonly used today.

Though the size of the dots varies, the number of dots per inch for the screen density used, does not. The lightness or darkness of tint resulting is dependent on the size of the dots, not the distance they are apart. A mid-grey would result from a 50% screen – one where half of the area is occupied by black dots and half by white spaces. A 50% 65-dot screen will make the same shade of grey as a 50% 150-dot screen; the only visual difference will be the coarseness of the image.



The screen on the right has half as many dots per inch as that on the left, but both are 50% dot screens. The smaller the dots the finer the printed image. (I must point out that ‘dots per inch’ (dpi) in printing screen terminology is not the same as dpi on your computer screen or desktop printer. It’s a shame the computer industry has caused this quite different meaning and confusion. The equivalent of printing dpi on computers is ‘lines per inch’.)

It may be helpful to imagine a chessboard with its alternating black and white squares as this is precisely what a 50% screen is like – but obviously hugely larger than used for printing. In printing terms the dots (the squares on the chessboard) are usually (though not always) round, but still in a regular grid. The important fact is that half the paper will be covered in dots and half by the spaces separating all adjacent ones.

With ‘continuous tone’ dot screens, as the name suggests, there is no variability in physical or visual dot density, unlike in photographs, where the dots vary in size across the whole image, giving the illusion of light and shade as in the ink bottle example above.

At other percentage dot screens the principle remains. A 10% screen will have ten per cent of an inch occupied by dots and 90% by white intervening spaces. This will result in a much lighter printed colour. Crucially, the colour of the ink is still full strength. The lighter colour we perceive is simply because our eyes cannot resolve the dots and spaces. It is by using screens of different percentages of the solid that different shades are achieved and screens in increments of 10% were widely used in pre-computer days.

We have seen how the use of two colours, differently screened, can make a variety of other colours. It can therefore be appreciated that to get lighter greens we could use 50% cyan with solid yellow. By using different dot screen percentages the shade is varied: 40% cyan over solid yellow will lighten the green more, and so on.

From left to right, the cyan content is reduced though the yellow remains constant. The combinations are 50c/100y, 40c/100y, 30c/100y, 20c/100y.

An example of screening both cyan and yellow. The above combination is 20c/30y, giving a pastel green that is neither blue nor yellow dominant.

Much can be achieved using just two colours with various dot screens (tints) combinations. Though there are practical restrictions to ink coverage on press, there wasn't, and still isn't, a restriction to the use of just two colours, and a whole range of colours can only be achieved using three colours, or even all four. Brown, for example, requires cyan, yellow and magenta.

A range of browns requires three colours and the above example is 50c/70m/100y. Again, there is no brown ink.

Some colours can be constructed in surprising ways. The obvious way to make grey is to screen black only. Black is a very 'hard' colour and even a 50% tint still gives a very dark and harsh grey. Returning to our Underground diagram example, the Jubilee Line grey used when the Line opened was made up of a 30% black (30k). However, more soothing greys can be made using cyan, magenta and yellow and possibly no black at all.

The above greys are, left to right: 30k, 30c/30m/30y, 10c/40k. The addition of a small amount of cyan in the right-hand sample helps soften the harshness of the black, though this may not be apparent on a computer monitor, which is using very different technology and a major subject in its own right. Unless you have a properly colour calibrated monitor you cannot evaluate printed colours on it, and different software will make different attempts at it, compounding the problem; the same applies to your printer.

All this only works because the inks are translucent, allowing light to pass through them. (Inappropriately, they are referred to in the trade as 'transparent inks'; if they were truly transparent, we wouldn't see them at all.)

Colour Breakdowns for a Proposed Underground Diagram

The following table records the screen values I used on my publication 'The London Underground: A Diagrammatic History' and I believe providing the optimum colour differentiation between Lines. These are neither those used in the past, nor now on public issue travel maps. I believe many of the present colours are a bit too dark; my colours are brighter and more distinct. The principles of how the artwork was produced in pre-computer days was the same, irrespective of the colours as printed – and these colour make-ups are just as valid today for computer generated artwork.

	CYAN	MAGENTA	YELLOW	BLACK
Bakerloo	50%	70%	100%	-
Central	-	100%	100%	-
Circle	-	10%	100%	-
District	70%	-	100%	-
Jubilee	10%	-	-	40%
Metropolitan	100%	100%	-	30%
Northern	-	-	-	100%
Piccadilly	100%	70%	-	-
Victoria	100%	-	-	-
Waterloo & City	50%	-	30%	-

So, it can be seen from the above table that the four process colours are each used, severally, across the ten Lines. If the list is examined, it can be seen that the plate used to impart cyan ink to paper, includes three different tints and three solids.

The Drawing Origination 'Overlays'

It is now appropriate to see how the original images were produced in preparation for the photographic process that followed, which later on allowed the four plates to be made.

The basic principle was that every image that eventually needed to be printed as a visually different colour, or shade of a different colour, was created on a separate piece of material called an 'overlay'. From the above table it can be inferred that ten overlays would be needed (ignoring station names for now).

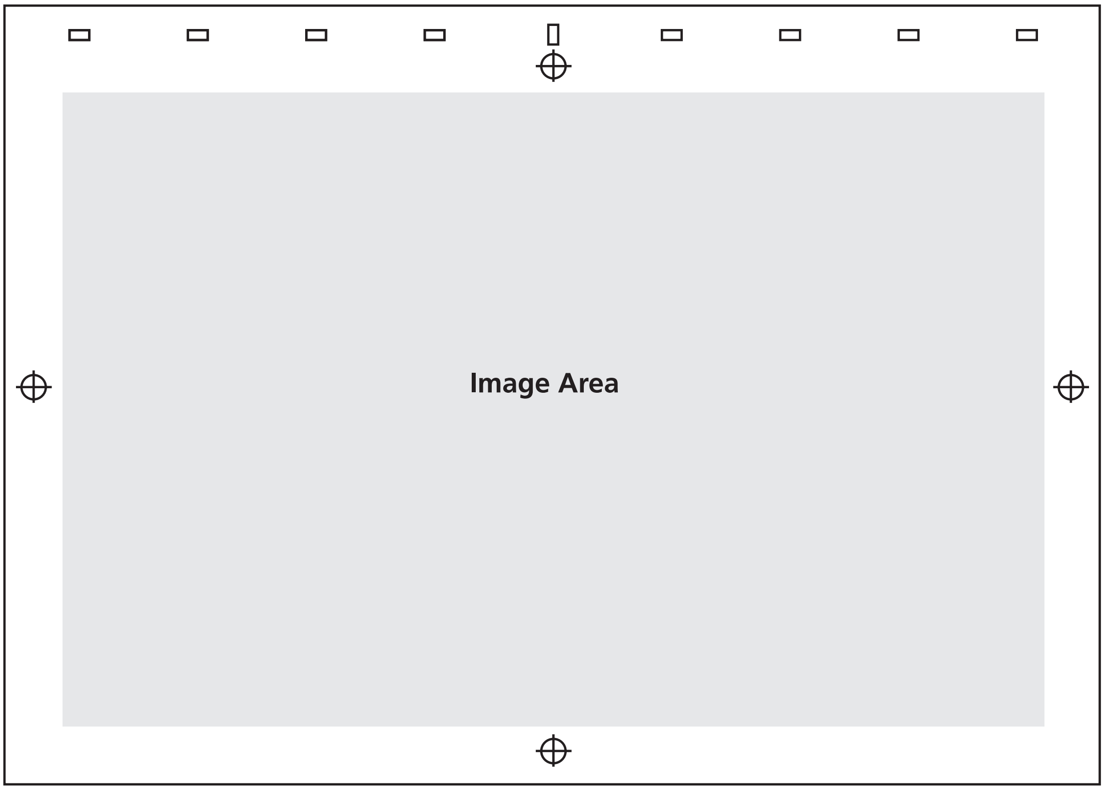
Overlays had to be translucent otherwise the draughtsman would not be able to see what he was doing. During the process of producing the drawing the overlays had to be piled on top of one another and, critically, had to fit each other as a complete set absolutely perfectly. The larger the drawing the more difficult achieving this became. Whichever overlay the draughtsman was working on at the time would be on the top and the work was done on a 'light table'. This was a very large table with a glass top with rows of fluorescent tubes inside. The lights were controlled by dimmer switches as the more overlays were piled on the more light would be needed to see through them all.

Artwork was often produced oversize and reduced photographically later on. This had the effect of sharpening the image. With something as large as a poster this may neither have been practical, nor necessary.

Now relegated to the corner of a room, when in daily use and on which overlay artworks were being created, this light table would have had access all round.

In order to ensure the overlays fitted accurately, a punch register system was used. For a job like drawing the Underground diagram, the artwork was for Quad Royal sized posters (40x50 inches, or 1016x1270mm) and the overlays would have to be bigger than that so that registration marks (the cross-hairs round the outside that would be trimmed off the paper after printing) could be included. Those cross-hairs allowed the overlays to be placed accurately on top of one another, but a better system was needed to hold them in place. If an overlay moved while being worked on it could cause a great deal of re-working and loss of earnings. This cannot be under-estimated.

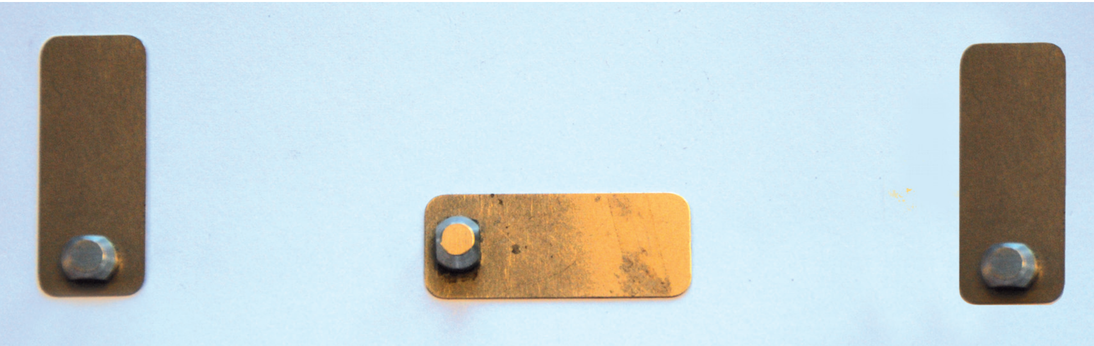
Consider now a conventional hole punch for punching paper to put in a ring binder. Something very similar was used, but massively larger, to punch a row of three to nine holes (depending on the size of the image) along the long edge of the overlays before any drawing was done. The 'register punch' was a big, heavy and expensive piece of equipment. It was very like a light table but with a heavy-duty lever system along one edge that allowed the drawing overlays to be punched.



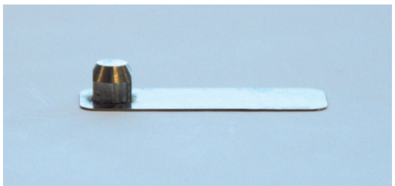
The above illustration shows what one overlay looked like before any drawing started. The row of rectangular punched holes has one vertical in the centre, with horizontals on either side. When the overlays were being worked on, floating 'register pins' (studs) were used from below and these pins protruded up through the holes and were up to about 5mm tall to allow many overlays to be fitted. It was commonplace for at least a dozen overlays to be needed for any given job and I recall one which required over twenty.

The register pins were a tight fit in one dimension but slightly under-size in the other. This allowed the central pin to move a bit up and down with the horizontal ones able to move slightly left and right. The combination meant the overlays could not move relative to each other. The four 'target' cross-hairs were drawn on after the holes were punched and these had to be done with immense precision. Failure to do this would mean overlays would not fit.

Apart from ensuring the overlays all fitted, the system allowed the sequence of them on the light table to be swapped above and below one another. That said, the size of the overlays inevitably meant a bit of movement at the far bottom edge from the punch holes and they were therefore secured using double-sided tape, thus reducing the speed of swapping overlays, though essential to retaining fit.



Looking down on them, three register pins that sat beneath the overlays. The central one was inserted in the vertical rectangular hole while those to the left and right went into the horizontal holes.



Sideways on, the height of the pin can be seen as tall enough to take many overlays one above the other.

The Demands of the Materials for the Overlays

A variety of materials existed for different aspects of drafting; by the 1970s more and more of which were made using polyester-based substrates. The primary virtue of this was its dimensional stability in differing humidity and temperature conditions. This property was of indispensable importance when one sees that for most jobs there was a need for multiple overlays. For many decades up to the late 1900s less stable materials were all that were available and caused huge problems.

In order that the overlays could be reproduced to a high quality, the photographic techniques required them to be exposed to film by intense ultra violet light and this dictated that only dense black or red images be used for the original drawings, so the light could not penetrate the image areas. The colour inks that eventually represented these images on paper had no bearing on what colour they looked like on the original overlays. Irrespective of printed colour, all overlays had images only in ultra-violet resistant black or red. Today's concept of designing on a computer screen and experimenting with colours did not exist then and the draughtsman would have to refer to colour charts and a lot of imagination until completion of the artwork. It was only at proof stage that any semblance of colour reality could be assessed.

'Repro' (jargon for 'reproduction')

It may seem that I am jumping out of sequence now, but as stated earlier on, no drawing of artwork could be contemplated without due deference to how it would be used to make the printing films, and from those, the printing plates.

The type of film used for this 'repro' work was called Lith Film; it was a very high contrast film that reproduced only total black on the developed film, or nothing at all. In other words, it did not record light and shade as on panchromatic, continuous tone, ('snapshot') film. The two drawing colours that best resist exposure to it are as stated above, black and red – but even these had to be dense images that completely resisted the passing of light through them at the time the image was exposed to the lith film. At some point between drawing and printing, for practical purposes, most overlays would need to exist both in positive and negative form.

That apart, in some circumstances there was also virtue in keeping items that would eventually reproduce in identical colours on separate overlays. Therefore, though the Underground diagram's grid was reproduced in Victoria Line blue, it had also appeared in black in other editions. By keeping the grid on a separate overlay from those of the Victoria and Northern Lines, this provided no difficulty. Indeed, with it separated onto its own overlay, there was no reason why it could not be green, red or any other colour. In addition to the ten overlays in the table above that represent the individual Underground Lines, these others can be added to our colour breakdown list.

	CYAN	MAGENTA	YELLOW	BLACK
Border/Grid	100%	-	-	-
River Thames	30%	-	-	-

If further colours were required, the draughtsman simply made further overlays and the list got longer. There was no theoretical limit to how many overlays could exist for any job, though the practicalities of maintaining accurate registration when a draughtsman could be looking through several sheets of drawing films, must be kept in mind. It could get very complex.

Drawing Techniques of the 1960s to 1980s

I cannot say when the following methods and techniques started and as with all technologies, they had evolved and didn't start or finish to nice neat historical decades. My own involvement started in the mid 1960s and most of what I am about to describe had taken a firm foothold by then, but got more sophisticated.

Strictly speaking, over the final twenty or so years of these techniques, there was less and less 'drawing' in the true sense of the word. Whilst a pen and ink was still sometimes used for some fine linework, other more versatile techniques had largely supplanted them on the grounds of both speed and quality.

The creation of a set of overlays could be achieved in a variety of ways; no one technique was suited to every kind of job.

Positive Overlays – Materials

I must say from the outset that there were many different drawing materials available over the years, in both standardized cut sheet sizes and also in roll form. They varied in translucency but all were very easy to see through, though none was glassy clear. It is impractical to go into detail here so I will concentrate on those I used most extensively.

As noted above, most, if not all, overlays would need to exist in both positive and negative as a means to the eventual end. As such, some original overlays would be produced in positive and some in negative, according to convenience and practicalities.

Fine linework could be drawn in ink, in positive, or 'scribed' negative in a process very similar to etching, more of which below. For positive drawing, there were many choices and, crucially, the right black ink was an essential partner to the material. Some inks worked well on some materials but were hopeless on others. The two materials that most dominated my work were Astrafoil (trade name) and Ozatex (trade name).

Astrafoil was available in flat sheets in three imperial thicknesses – 0.003", 0.005" and 0.010". Much storage space was therefore required for the drawing office stock. It provided a really pleasing surface on which to draw and the inks used would not be allowed nowadays owing to their oil-based chemical composition (see Appendix). These inks actually etched into the Astrafoil as soon as they dried (which could take a minute or so). There were many issues.

Astrafoil had a gloss surface one side but matt for the drawing on the other. The surface could not be drawn onto until it had been rubbed down with a medium hardness rubber. The ink would not take otherwise. Astrafoil was not particularly dimensionally stable and would expand and contract over time. Bearing in mind, with revisions, these overlays could be used for years.

It also had another serious drawback – it was very brittle and easy to shatter if not handled with care. (The thinnest gauge was almost unusable if you so much as breathed on it.) I expect readers can imagine the draughtsman's (and his boss's) displeasure when an overlay shattered after weeks of work and the liklihood was starting again. (Computers exert the same dismay on us when we delete a file by accident and have no back up.)

As can be imagined, ink that had etched into the surface could be time consuming to remove when revising. It had to be scraped off with a sharp flat blade and the slight groove the etching ink had caused made smooth with the same implement. This required skill. Without a flat surface, that again had to be rubbed down, it was impossible to draw something new over it.

Ozatex (and others similar from other manufacturers) solved a lot of this, but came with its own drawbacks. It too was available as flat sheets and also in rolls, the latter of which were obviously easier to store, though it could be a nuisance to get flat when cutting from near the end of the roll.

The surface didn't need any preparation and either side could be drawn on. It was polyester based and so dimensionally very stable, furthermore the inks did not etch and were therefore easier to scrape away for revision.

Positive Overlays – Drawing Instruments

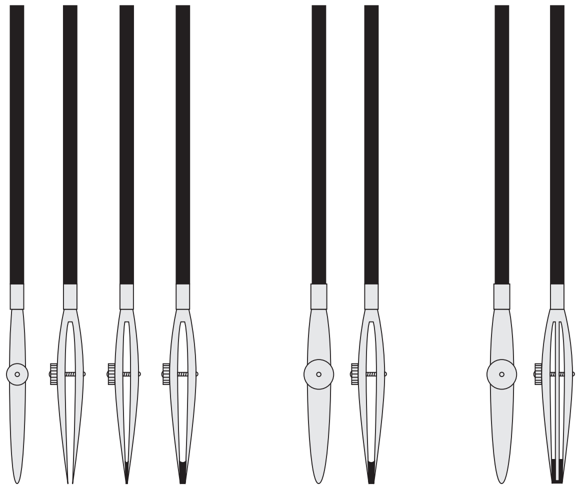
Many readers will be familiar with Rotring-type (another brand name) pens and there were others. I detested these as the only inks that would work in them were too watery and producing lines black enough for repro was almost unachievable. Even with the thinner inks essential for them to work at all, they still clogged up all the time. One also needed a range of them to draw different line thicknesses. In my world, they had no redeeming features whatsoever.

I used a 'ruling pen'. This one pen was capable of producing very fine lines and also those up to about 1mm thick (though we worked in thousandths of an inch and not millimetres as noted above and as for material thicknesses).

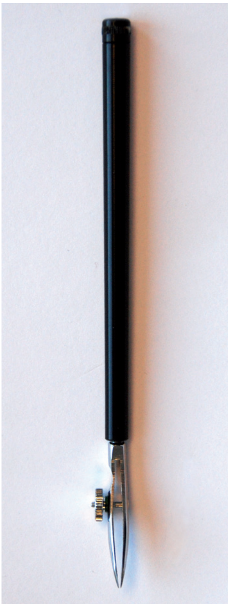
Thicker lines could be drawn using what was called a 'border pen'. These worked precisely as for the ruling pen, but had more substantial forks and could hold more ink. Really thick lines were drawn using a 'cartoon pen'. The same mechanical principle applied, but with a third, non-adjustable central prong, just shorter than the two outer ones which were in contact with the drawing material. The central prong effectively divided the ink into two separate reservoirs and stopped it from flooding. Many other specialist variants were also made but are beyond the scope of this article.

We used to use a German-made ink called Hausleiter on Ozatex. This too was a water-based ink but nevertheless produced dense linework. It was very black but needed maintenance. It came in very large bottles which even in a busy office would last years. On the debit side, it had to be frequently and vigorously stirred as sediment would sink to the bottom within a short space of time. Failure to do this resulted in insufficiently black lines and so poor resistance to ultra violet repro exposure. It was also prone to chipping off the Ozatex if the material was flexed too much and the ink too thickly applied and the ink wasn't just right for viscosity.

Ozatex was also very hard and blunted drawing instruments surprisingly quickly. One of the skills needed by draughtsmen (any many didn't have it) was the ability to sharpen one's ruling pen. One could work on Astrafoil for weeks with no need for sharpening. Expensive ruling pens with tungsten carbide tips were also made but could damage the drawing surface more easily.



The four illustrations on the left show the ruling pen's adjustability and ability to draw different thickness lines. The two in the middle represent a border pen, with its broader forks and so greater ink capacity, though it could not actually draw lines much thicker than a standard ruling pen. For really thick lines a 'cartoon pen' was needed, as seen to the right.



On the left is a ruling pen. The two forks were kept apart by a small thumb wheel. Turning the stiff wheel allowed the forks to be opened or closed to increase or decrease the line thickness produced by the ink that was in between. The ink was necessarily quite viscous so as to not pour out the end. It was essential to keep the pen vertical to produce crisp lines.

In the centre and right is a 'contour pen' which worked to the same principle but had an offset swivel (like a shopping trolley wheel). Whereas a ruling pen was used along a straight edge, a contour pen was used freehand, but still upright, for drawing continuously changing wavy lines. Mastering these took some time.

Negative Overlays – Materials

There were two principle options in regular use – one for ‘scribing’ and one for ‘peel coat’. Scribing was suited to fine linework, up to about 1mm thick, whereas peel coat for thicker ones, and also for larger irregular area shapes.

For fine linework we used a material called ‘Stabiline’ (brand name) and two different tools, a ‘straight line scriber’ and a swivel ‘tripod’, the former doing the equivalent job of a ruling pen and the latter to that of a contour pen. They used sapphire chisel tips, more of which below.

Stabiline was a completely clear polyester base material, but with one surface orange powder coated, not entirely resistant to ultra violet light, but usable with lesser exposures. The sapphire chisel tips scraped away the coating revealing the clear base material and effectively creating an orange negative.

Peel coat materials, colloquially known as ‘cut & strip’, were widely used for photographic masking in ‘repro’ houses as well as for ‘drawing’ by draughtsmen. (I can’t go into this here.) The material usually came in rolls, and had a clear polyester base film with a thin translucent red membrane adhering to one surface. There were several makes and qualities.

The use of this material for ‘drawing’ is less easy to picture for the layman. To get the basics out of the way, it must be understood there were no pens or inks used – just knives. Cut & strip also produced negatives in the same way as Stabiline, it was just that the lines were thicker – limitlessly thick.

When an area of this membrane was cut through with a blade, it was then possible to peel it away from the base film revealing the clear base underneath and thus creating a negative image. Only the red membrane was peeled away; the substrate was not cut through at all. Care was needed.

I should add that there was an earlier and then contemporaneous scribing material called Astrascribe. This was Astrafoil with both sides glossy but one with a thin orange coating. The use of this was the same as for Stabiline but the similarity in its use stopped when the work was complete. Stabiline formed a negative image and that’s how it remained. Astrascribe had to be converted into a positive image by the application of ink and chemicals. This was a hazardous process, carried out routinely every day in the drawing office.

The starting point was to just have the Astrascribe sheet on the light table and nothing else. It had to be taped to the glass on all four sides and with no gaps under which the chemicals could creep when applied to the orange surface.

A thin black ink was applied from a gallon tin onto wadding. Rubber gloves had to be worn and the wadding was wiped generously over the whole surface. Where the orange surface had been scraped away, the ink etched into the revealed surface. In due course the whole of the orange and clear areas were covered in ink, with the orange coating resisting it. The ink dried very quickly. With this complete and the ink safely put away with its cap on, industrial methylated spirit was then applied, also with wadding pads. This cleaned the orange coating away completely, revealing the clear gloss surface, now with crisp etched black lines. About a dozen pieces of wadding were used and all this ended up in a bin and highly combustible. Not a process for the 21st century.

Negative Overlays – Drawing Instruments

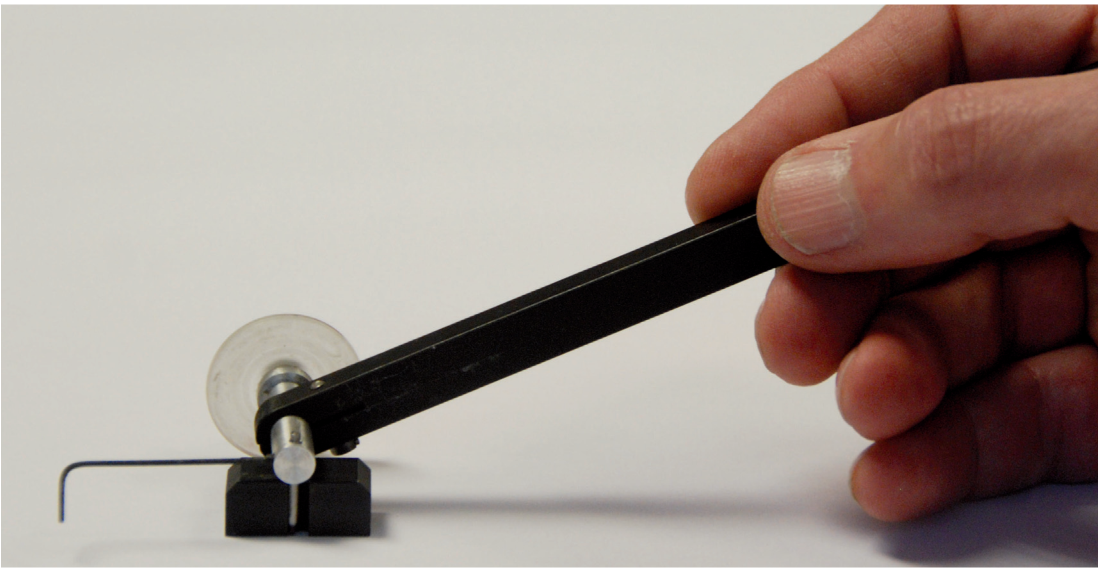
Scribing tools came in two forms – one for drawing along straight edges and plastic curves and one for freehand work such as needed for contours on geographical maps.

Scribers were fitted with expensive and fragile sapphire chisel tips which were available in 0.001” (thousandths of an inch) increments from 0.003’ upwards to about 0.030”. Other and even more expensive specialist tips were available for scribing double and even triple lines, and to different spacings. These were used, for example, when scribing outlined (knowing as ‘cased’) roads on geographical maps. A later development was cheaper steel chisel tips, but these were not very satisfactory and we gave up on them quite quickly.

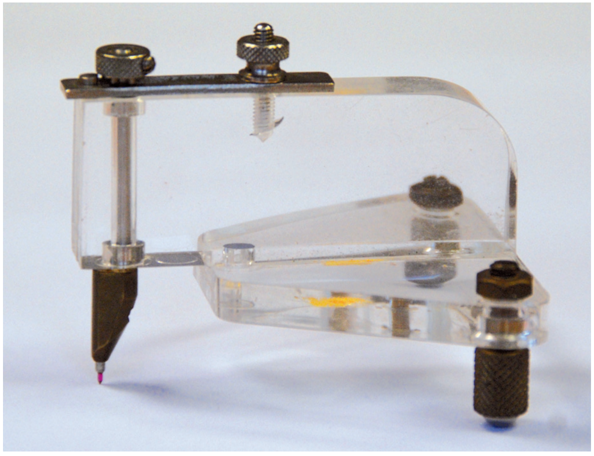
Of necessity, we would have several different straight line and tripod scribers set up at any one time, each with a variety of different thickness tips, which were interchangeable between straight line and tripods. The thinnest tips were very easy to chip, and even the thicker ones needed treating with respect. When not in use we used to push a small piece of rubber over the tip to protect it.

Scribing was not really a viable option for lines thicker than about 1mm (0.025”). If much thicker lines were required, such as for an Underground map poster, scribing was not suitable, though it was all right for the grid for example, where cut & strip could not cope with peeling out thin lines.

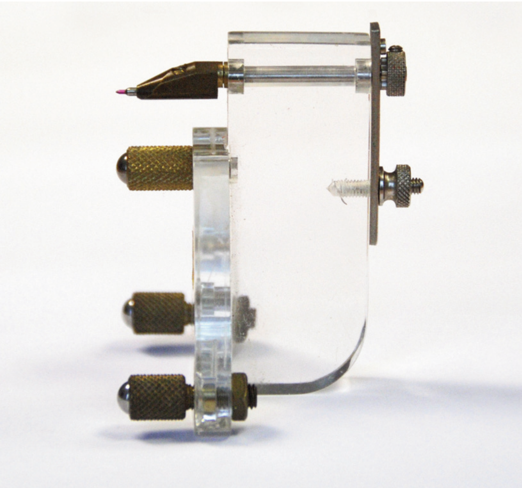
A straight line scriber. The small red protrusion at the bottom is the sapphire tip in its vertical cylindrical metal housing.

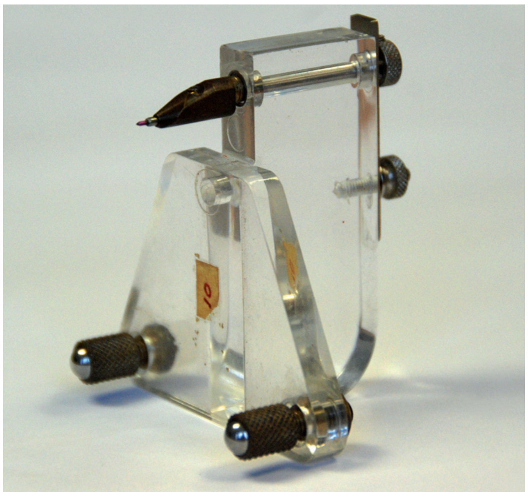


Just like a rule pen, a straight line scriber had to be used vertically to produce clean lines of the right thickness and the set up was all important. The sapphire tip had to protrude precisely the right distance from the horizontal fixed axle to match the radius of the plastic wheel. A small block with a vertical slot was used to create the correct distance and the tip was held in place by tightening a tiny allen screw against a small flat on the vertical metal tip housing. The angle of the handle could be rotated, relative to the axle, to suit the comfort and preference of the user. The allen key is seen in position in this photograph but both block and key were removed once the set up was complete, as shown in the earlier photograph.



Not used in the job described in this piece, swivel action 'tripod' scribers were used extensively when producing linework for contours and so on. They were made of thick perspex so the Astrascribe or Stabiline and tip could be seen during use.

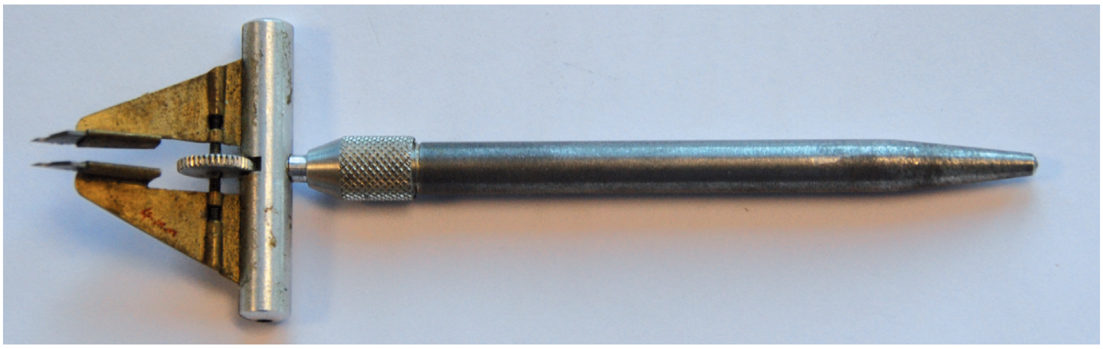




The tripod also had to have its tip at a precise distance from its underside and matching the height of the two rear leg ball bearings. These allowed the whole tool to be steered at will by pulling it along gripping the vertical central bar. It was important with both straight line and tripods to press hard enough to remove the surface coating but not so hard as to dig in and damage the tip.

In the right-hand photograph a small piece of tape can be seen with ‘10’ on the underside – this was the width of tip (0.010”) fitted to this particular one.

A double cutter for creating thick lines which would be peeled out, creating a negative. The blades were on the end of a slightly sprung arrangement. This tool could be used freehand for curves or, by tightening the knurled screw at the bottom of the handle, along straight edges.



The knurled screw was used to adjust the spacing of the two blades and thus the thickness of line. The pair of thin brass plates were sprung along the centre line of the adjustment wheel.

Creating the Design (an Underground Diagram in this Example)

Having reviewed the principal instruments in daily use, I can now move onto the process of using them to create the overlays which each carried the individual colour components. I am only using an Underground diagram to explain the principles of how overlay artwork was constructed, because it is an every day item familiar to most readers. However, these principles were just as applicable to all manner of proper geographical maps – and pretty much anything that was going to be printed in colour.

At this point it must be understood that a draughtsmen and/or cartographers couldn't easily just start the creative process out of their heads. Making alterations as one went along was not viable owing to its time-consuming and fiddly nature. The ease with which computers afford alterations progressively and at will must be expunged from your thoughts – this simply didn't happen in 'manual' days.

It may be supposed that each Underground Line would be produced, one at a time, but this wouldn't work as no matter how carefully the design had been drafted, the design would inevitably be subtly adjusted as work progressed. The design would have had to have been very carefully worked out complete on a sheet of Ozatex, as a pencil draft – this being much easier rub out, alter and get right. Over a very large plastic sheet of graph paper, the geometric layout was sketched, simulating lines about 5mm thick, using parallel pencil lines.

The approach to designing a railway network diagram is quite unlike that for a geographical map and I cannot go into the detail here. In brief, designing an Underground 'map' requires understanding the visual balance to be struck between line thickness, typeface and station name typesize. The rigid constraints of the geometry cause the lines to be projected around the station names. In other words, the names have to be positioned first and the lines constructed around them, ensuring sufficient space to avoid ambiguity. This is counter-intuitive and not the approach for geographical maps. (This is equally true when using a computer and many 'designers' would benefit from understanding this.)

With the pencil draft complete, punched and placed on a set of register pins, work could start on the first overlay. However, as noted above, the station names were needed first.

I would have started by typing the names on a typewriter, in Line order, ensuring none was missed. The typed list (known unsurprisingly as a 'type list') would have been sent to a firm of typesetters by post and they then typed them out all over again, using the typeface I requested, and to my chosen point size. A couple of days later I would receive from them a roll of bromide (a photographic high contrast black & white paper-like material). This was just like getting your photographs printed. The bromide could be in several manageable sheets or on a roll.

Knowing that all images had to be solid positive black or negative, so as to be able to see what I was doing, the station names overlay would need to be on a clear positive sheet with black positive type. The railway Lines would be negative red cut & strip. The black outline for part of the Circle Line would be positive, drawn in ink. The interchange black rings would be positive black, but I wouldn't have wanted to draw all those thick circles, importantly with white centres, using ink. Another technique was therefore used for the interchange rings and station names.

Lettering on any map or diagram would need to be black, irrespective of the colour it would eventually be printed, and it needed to be on its own clear overlay. A separate overlay would be needed for each lettering set to be printed in a different colour. I state again, at overlay stage, all lettering had to be dense black.

The station names would need to be positioned individually and transferred from the white bromide sheets to a clear adhesive film. This could be done in the office.

The PMT Camera

We had a couple of small format cameras in the office which allowed copying the typeset station names, from the bromides, onto a thin, clear, adhesive film, which came in a variety of convenient sizes.

PMT is the abbreviation for Photo Mechanical Transfer. The camera was very similar to the 'process camera' which would be used later to make the printing film positives, though the latter was enormous and far more sophisticated and versatile – more of which later.

Located in a darkroom, the image from the original (in this instance the bromide) was copied, through the PMT camera's lens, onto a photographically sensitive negative paper.

The paper negative was then removed from the camera and fed through a pair of rollers with a sheet of clear adhesive film. The rollers pulled them both through a chemical developer bath and then squeezed them together. A wait of up to a minute was then required while the negative transferred its image to the clear film. They were then peeled apart, the paper negative discarded (they were not re-usable) and the clear film washed in water. It was now ready to use.

The positive was a sheet of clear base film with a photographically sensitive

A PMT camera. These were used in a darkroom and not in daylight as in this photograph.

At the bottom a glass sheet can bee seen and this measured about 450x600mm from memory. The bromide to be copied was placed beneath the glass, which was hinged along the back edge. A vacuum was then applied to hold the bromide completely flat.

The white sheet at the top is covering the top glass (it has a set of film size dimensions on it for positional guidance but would not have been in place when the camera was exposing the film). The negative to be exposed was placed here emulsion side down. When the lid was closed a vacuum was applied to hold that completely flat as well.

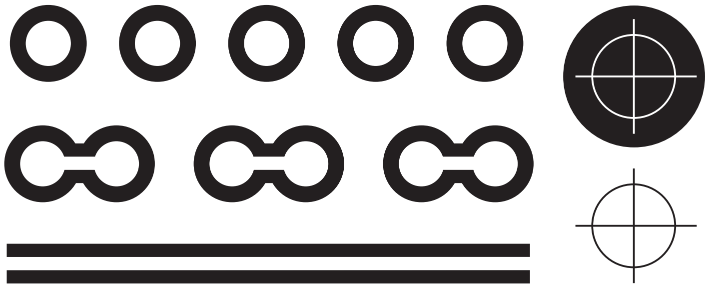
The camera had to be set to enlarge, or reduce the image, or set at 100 per cent scale for an exact size replica. One of the handles on the orange front panel was used to focus the lens and the other to set the scale. The operator looked down through the top glass panel, through the lens (below the orange panel and not visible in this picture) to set it up. Other controls were for timing the exposure.

The camera could ‘photograph’ the image, using the halogen lamps to the left and right to expose the film, reflecting off the lower level frame, through the lens, onto the paper negative above.

Other clever things could be done using back lighting but I’ll leave it at that for now.

surface, on a paper backing sheet. The image was on the front of the film and could therefore be damaged in use. When used, the film was cut with a scalpel around each name and peeled off the backing, ready to be stuck to its overlay.

All the station names were now on adhesive clear film and I did the same with the interchange rings, drawing just a few and replicating them dozens of times onto clear adhesive film. The rings would also be cut out with a sharp scalpel and stuck in place on a clear overlay, not pressing them down to hard in case they needed lifting and re-positioning slightly as the design grew.



An example of a few drawn features to be duplicated onto adhesive film. The double line could be cut into appropriate short lengths to construct different interchange configurations.

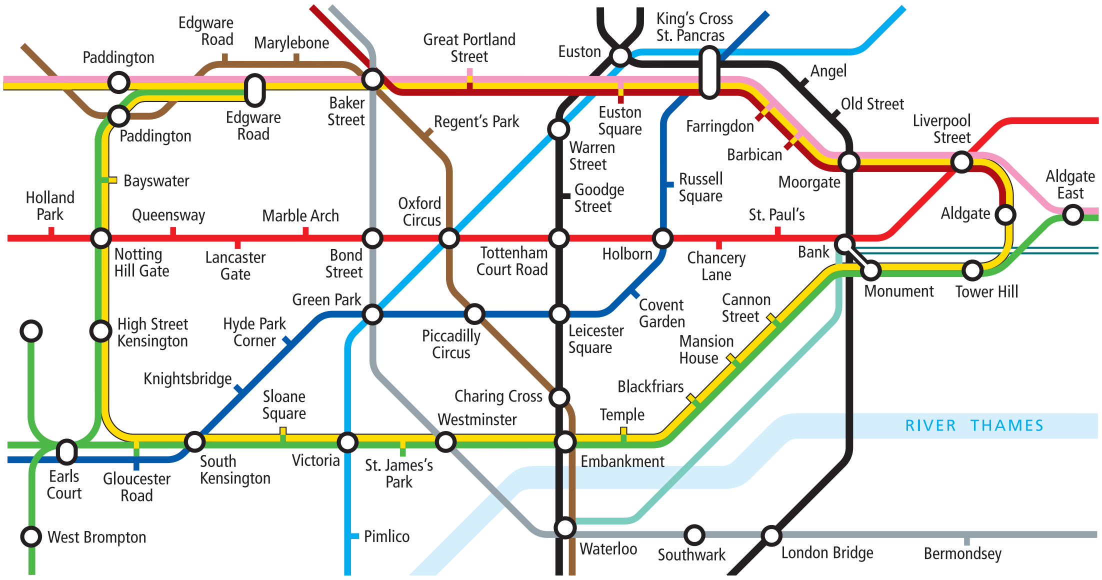
The Negative Cut & Strip Overlays

With the Ozatex draft at the bottom and the first few station names in place on their clear overlay, the first sheet of cut & strip was fitted on top and all the Underground Lines cut and peeled out progressively, swapping overlays incessantly and working outwards from the most difficult area, while also progressively applying the interchange rings and station names.

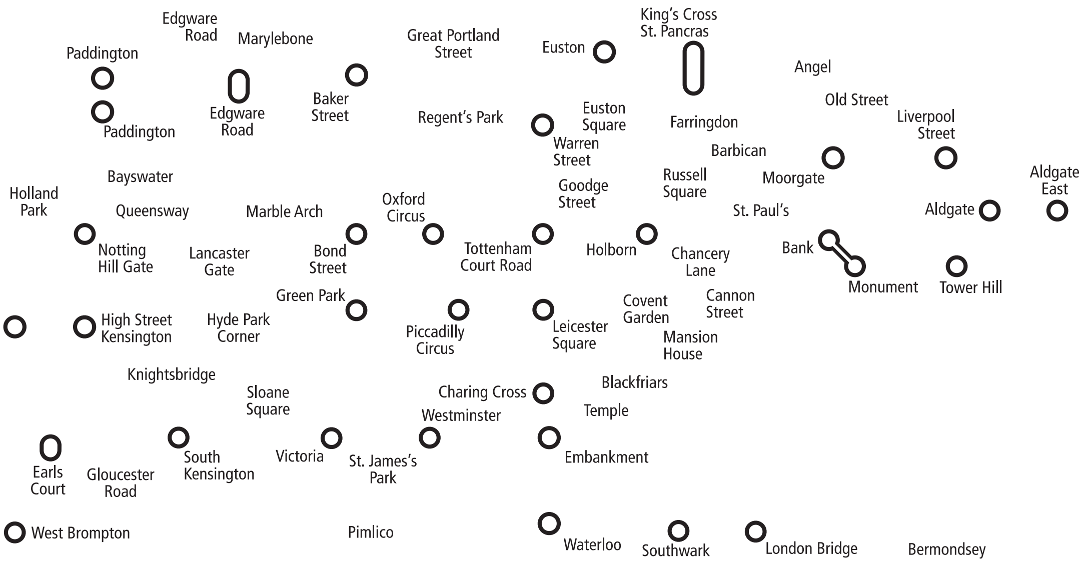
The hand-held double cutter tool was used, with its pair of blades adjusted to the right spacing. With the swivel locked to stop its action, the double cutter was very carefully guided along a straight edge, not pressing too firmly against it otherwise the blade spacing would be affected. Changes of line direction were done by eye, having released the swivel lock, without the straight edge and as uniformly as possible.

The fragmented black outline for the Circle Line was drawn in positive, in ink, when everything else was finished. The grid could be drawn in ink on Ozatex in positive, or scribed on Stabiline in negative, according to preference.

The following pages show example sections of some of the overlays. For this to make any kind of sense, I have first shown the finished design. This is part of one of my own and avoids the alleged confusion some users have in trying to read more into the information than is being offered.

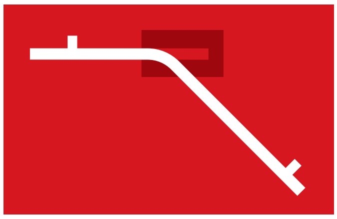


The central area of a possible design. If some users think a single ring interchange is different in real life from one shown as a double 'dumbbell' then this avoids it. Confusion or not, would users actually plan their journey by a different route to avoid a 'dumbbell' interchange? Who knows.



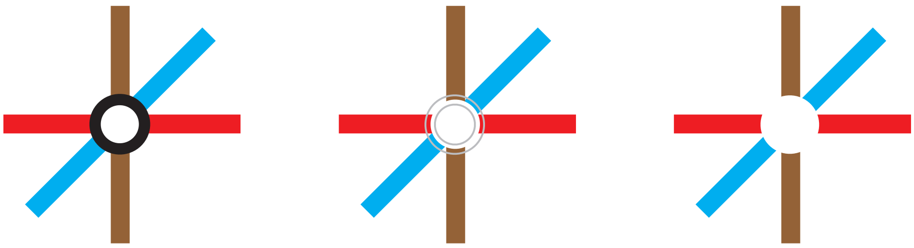
The station names overlay, on clear film. The interchange rings are demonstrated here on the same overlay as both will print solid black (100k). This was perfectly acceptable, however, they could be on their own clear overlay for greater flexibility.

Using a sheet of peelcoat (cut & strip) the above represents the Bakerloo Line negative. The perpendicular station ticks are just a bit thinner than the line; the length and thickness of these need to be correct to look right.



Even with the best planning and care, mistakes happened and needed correcting. Reels of red ‘litho tape’ were available and worked just like clear adhesive tapes. In the above example, starting from the top left, I have shown the progression of horizontal line projecting too far right of the diagonal downturn. Tape would have been applied and the double cutter cut through it in the correct place and then turning south. Revisions would be done the in same way.

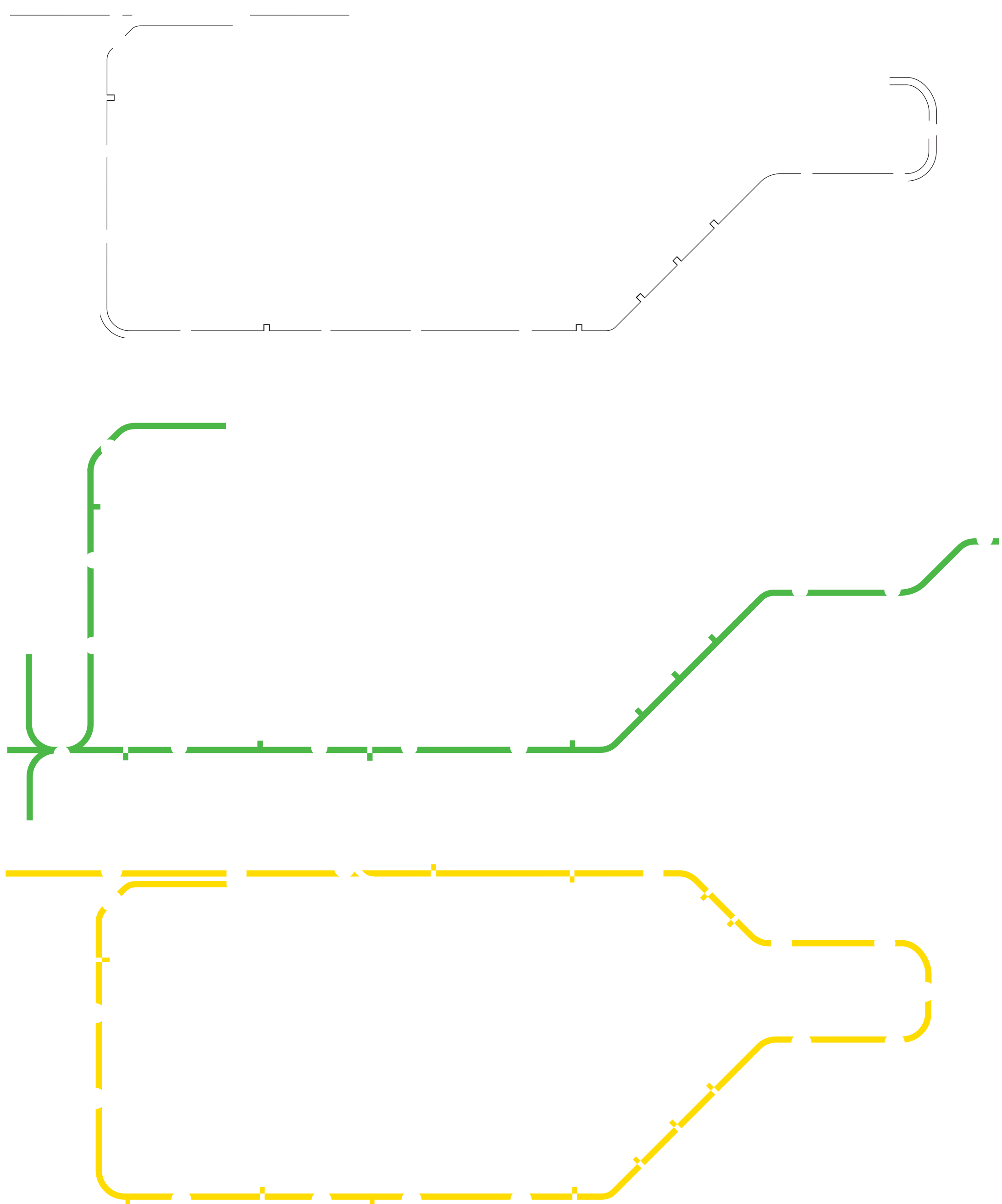
The Bakerloo negative overlay would be used three times when making the printing positives – for cyan, magenta and yellow (50c/70m/100y). The black interchange rings however would need a white centre – no white ink is printed. Therefore there had to be a means of breaking the brown line on all three printing positives. To do this, a separate clear overlay was created and black disks stuck on, precisely over where the interchange rings were. Using the two overlays together on the camera, as one negative, the line would be broken on the resulting positives. Note the two near bottom are offset for Embankment and Waterloo, and at the top for Baker Street.



But it was more complicated than that (and still is even with computer production). Solid black should be made to 'overprint' the other three colours to ensure a good fit on press.

To the left is what it should look like when printed. The middle example has two grey rings and these are only for demonstration purposes to show the inner and outer limits of the black ring when printed. You will see that the three Line colours are actually cut off ('masked') midway between these limits. The right-hand example is how the overlays would actually print with the black ring slightly overlapping (overprinting).

The black disks from the clear overlay were of a slightly smaller diameter than the interchange rings themselves.



Top: the fragmented 'casing' black linework for Circle Line. The lines were only wanted where the yellow was not contiguous with another colour.

Centre: shown in green here for context only, the District Line positive overlay in its finished state, with all its gaps so as to not overlap any adjacent colours. Note also the gaps for the interchange rings.

Bottom: shown in yellow for context, the Circle Line. Note also how the station ticks are not allowed to intrude their adjacent coloured lines.

Intermediate Proofing

Computers spoil us in so many wonderful ways. In case you think otherwise, I have been using computers for 25 years and wouldn't want to work any other way. Just writing this piece reminds me of the many horrors of manual cartography, though it certainly taught you to be careful and understand printing. Most of today's computer users would benefit enormously from this knowledge and training in printing ought to be mandatory.

Having made all those overlays there was an obvious need to check them, both for content, colour-separation and fit. Remember, at this point, the draughtsman or cartographer had seen nothing in colour. Making proofs nowadays is ridiculously simple, takes minutes and you can have as many as you want; back then, just making one copy would take a couple of days of solid effort – and was fraught with the same problems of the 'inking up' process described earlier.

There were two basic options: 'deep-etch' proof, or 'photo proof'. The former required positives of the image area and the latter negative. I won't trouble readers with photoproofs but the processes were very similar for either with the latter unsurprisingly being photographic and taking just as long. For future use and revision, positives were easier to work on and it was at this stage, just before proofing, that a set would be made.

This was relatively straightforward and done in a darkroom. A cut & strip overlay would be placed on top of a lith film negative, already register punched to fit. The two would be placed on register studs in a large metal-framed glass vacuum frame and all the air sucked out, pulling the two inseparably together. An intensive bright light was fired at them for the correct exposure time. The vacuum was released, the two sheets of material separated and taken out and the film negative developed. This resulted in a completely clear film with black lines that fitted its cut & strip exactly.

Making a Deep-Etch Proof

The proof was produced from the positive overlays and was a one-off. Making, say, six proofs, would cost six times as much as one, and take six times as long, and for this reason usually only one was made. The method involved no photographic work in the normal sense and no printing.

These proofs were made directly from, and therefore exactly to the same size as, the overlays, onto a sheet of plastic known as 'White Astrafoil'. It was the same as the almost clear drawing variant and also polished on the non-use side but opaque white. As with its counterpart, it shattered quite easily, the impact of which will be better appreciated when you read on.

First, the surface of the blank sheet of material was prepared by cleaning it with a very fine abrasive to ensure it was free from grease. It was then placed in a cylindrical centrifuge cabinet of about six feet (about two metres) diameter. Whilst turning at about 90 revolutions per minute a bi-chromated gum solution was poured on near the centre. The centrifugal effect distributed the chemical as a quite even surface film.

This was allowed to dry after which time the Astrafoil was removed from the cabinet and placed in large 'flat bed' glass vacuum frame. The first of the overlays (the Central Line for example) was then placed directly onto the chemical surface and the vacuum applied, thus bringing the two sheets of material into intimate contact with one another. A bright light, high at the ultra-violet end of the spectrum, was then aimed at them having the effect of making the chemical areas, unprotected by the presence of a drawn image, harden; the chemical under the black line image areas on the film positive remained dry but soluble in the developer it was about to encounter.

The vacuum was switched off, the overlay removed, and the astrafoil placed on a flat working surface. It was then flooded with developer wiped all over until the unhardened areas of coating (those protected by the black lines) were dissolved away leaving a 'stencil' of hardened gum coating. This stencil then protected the Astrafoil base and a coloured dye applied (red in the case of this Central Line example). The dye replicated as closely as practical the actual visual colour required and was wiped on evenly with a pad of wadding across the entire surface. The dye etched into the surface of the Astrafoil making a permanent image. Water was then used to wash away the hard coating, revealing the white surface again with an image in one colour (red) representing the original overlay from which it was exposed.

The Astrafoil was then returned to the centrifuge, re-coated and exposed to the second overlay (let's say the District Line). This time green dye was used and the surplus gum washed off. And so the process went on, repeatedly, one coating, one dying up and washing off, for each overlay. At this point, for the Underground map, at least a dozen repetitions of dying up had been gone through and shattering the Astrafoil at any point meant starting again.

At the end of this process a proof was available for checking the accuracy of things like spelling, line positioning relative to one another (registration) and that everything was in the right colour. (It is all too easy for the draughtsman to put something on the wrong overlay – after all, he only saw black or red lines and lettering in positive and/or negative.)

The proof was also a useful tool for assessing the finer points of the design; for example, the grid, which could appear in a variety of colours, was in the correct one, so that its suitability can be assessed by the designer – he might see the proof and think it would look better in a different colour. Though the above process was laborious, and therefore expensive, it was still much cheaper than the cost of a reprint of several thousand copies should anything be wrong.

As can be inferred from this procedure, deep-etch proofs were not made using the 4-colour printing process described earlier – that was for later.

After the proof had been checked and the necessary amendments made to the overlays (and possibly the need for a second deep-etch proof) it was time to proceed to making the film positives from which the printing plates would be made. It was at this stage that the solid images on the overlays would be converted to their appropriate dot screen values required to make the correct colours when on press. The great virtue of the overlay system was that by reverting to the original overlays it was possible to make new printing film positives, as often as is desired, using different screen values, and into different combinations, to achieve any colour scheme required. The overlays, if handled carefully, could support many changes of content and thus serve for numerous editions over many years.

'Repro': Making the Film Negatives

It was commonplace to produce original overlays larger than would be printed. When making the final screened printing positives the photographic reduction would have the effect of sharpening things up as noted earlier.

I have to now refer back to earlier in this piece and the discussion about dot screens and 'dots per inch'. These dot screens had to be applied at the finished size and this was not necessarily the size at which the overlays had been produced. The final size was determined on a 'process camera'.

As stated, screens of different resolutions were widely available; they came in huge film sheets. These were expensive and easy to scratch and so had to be handled and stored with great care. A repro house would have had a variety of resolutions for use, usually at 120, 150 and 175 dots per inch and in 10% increments from ten to ninety per cent. This meant nine huge screens for each resolution. If a solid (100%) image was required, no screen was needed at all.

If the described Underground diagram was required to be printed at different sizes that were not hugely different, there was no reason why they could not be derived from the same overlays. However, a new set of 4-colour printing positives would have had to be generated for each desired printed size. As stated above, the final size was determined by the lens reduction (or none) of the camera, but the screen was never enlarged or reduced or it would alter the resolution.

Up to now all proofing had been done from the multitude of overlays at drawn size and not using 4-colour process. They now had to come together and at exactly the size required for printing. This coming together resulted in four film positives known as a '4-colour set'.

The first stage of making a 4-colour set from which the printing plates would be made was to set a 'process camera' to the appropriate reduction setting. Every overlay would be needed in negative on lith film and some in positive for 'masking' purposes (those disks for example). The films had to be at exactly the printing size and only when the set was complete could screens be applied.

When a full set of film negatives had been made, the high contrast nature of the film inevitably meant there would be minor blemishes in the form of pin holes. If left, they would show up on the printed paper and so had to be carefully painted out. A common brand of retouching fluid was 'Photopaque' and was applied with fine sable-haired brushes in areas of small detail in a job known as 'de-spotting'. It was a skilled and time-consuming job, not much fun, but essential nevertheless. It could be minimised by getting the camera exposures optimal and eliminating dust as much as practical from the overlays, unexposed film, screens and darkroom generally.

With thanks to Wikipedia, this is the only photograph I could now find of a process camera; this one made by a company called Littlejohn.

The overall structure was about eight feet (2.4 metres) tall as can be seen from the overhead gantry. At the left is a large belows arrangement with the lens housed in the rectangular frame in front of it. This could travel back and forth driven on the track below and thus allowing enlargement or reduction. Behind the belows is the darkroom, which was effectively the inside of the camera and actually a separate large room.

In the centre of the photograph the ‘copy board’ can be seen. This was a huge glass frame in which the original overlay would be placed and held flat by a vacuum. A set of register pins ensured they were all in exactly the same place as, one by one, each overlay was inserted, copied, removed, and replaced by the next.

To the right of the copy board are four multiple halogen lamp sets which could also be moved, and angled, relative to it. They could ‘backlight’ through the overlay and glass frame, or turned and moved between the lens and glass frame and aimed at it, for copying opaque images. The camera operator (a highly skilled job) also controlled the lights through a precision timer in the darkroom.

Inside the darkroom, immediately behind the bellows, was where the large sheet of lith film was also held in place by a vacuum and register pins, waiting to be exposed.

As I hope is obvious, a process camera was a hugely expensive piece of extreme precision engineering. Even in the early 1980s a pair of lenses (standard and wide-angle) cost thousands of pounds.

‘Repro’: Making the Film Positives

Referring back to the tables of overlays on pages 6 and 10, it can be seen that nine overlays needed to be combined to make the cyan film positive. With all the negatives at the intended printed size, the camera was no longer required. Attention now turned to a plain horizontal vacuum frame which had a substantial hinged lid. Called a ‘contact frame’, these were even bigger than the vertical equivalent on the camera and shared its darkroom space.

With yet another set of register pins used in this ‘flat bed’ frame, the first negative was placed onto a sheet of unexposed lith film with the relevant screen in between (or no screen if a solid image was needed). The vacuum was applied and through the negative the film exposed to an extremely bright light. The first negative and screen were then removed and the second negative and appropriate screen positioned correctly. The vacuum was re-applied and the film exposed a second time. Every negative required, for the colour being made, was exposed through its appropriate screen. The astute of you will have realized that the dot screens were negatives too. So, for example, to get a 10% positive image for printing, a 90% screen was used to make it.

As the undeveloped film only received light through the transparent areas of the negative and dot screen through which it was exposed, the rest of the surface of the film remained unexposed. Each negative, being derived from different overlays which had mutually exclusive image areas, thus permitted exposure through its own transparent areas and prevented exposure through its black ones. Therefore, the surface of the film was progressively exposed through each relevant negative but never over the same part of its surface twice.

After the last exposure had been made, the film, having been subjected to nine separate bursts of light in this example, could then be developed. What emerged was a sheet of positive film, combined to contain the images from all nine overlays, each screened to the appropriate percentage of dots and solids, and to the correct size to be printed. In turn the other three film printing positives, to represent, magenta, yellow and black, would also be made.

It can be seen from the overlay list that some negatives were used more than once and in conjunction with different screens. For example, the negative of the Bakerloo Line was used with a 50% screen when making the cyan film positive, a 70% screen when making the magenta, and with no screen at all when making the yellow; it was not required for the black.

The Cromalin Colour Proof

At this stage four sheets of positive film existed, each including solid black linework and lines made of black dots of different sizes. Visually each of the Underground Lines on each positive was a different shade of grey, or solid black, or not there at all – but it was all visually still black.

As stated earlier, the lines looking like different shades of grey were merely a result of our eyes’ inability to resolve such small black dots and the transparent spaces separating them, and whilst an experienced eye can sometimes spot an incorrect dot screen (‘tint’), it would be a brave man who would allow these four film positives to be used, unchecked, for plate-making and the subsequent printing of thousands of paper copies from them. Consider too that the four positives had been made completely in the dark; even with care it was not difficult to use a negative back-to-front or with the wrong screen. A ‘Cromalin’ (another brand name) colour proof was therefore made, directly from the 4-colour positive film set, so as to test and prove its accuracy of fit and colour content.

The purpose of this (second) colour proof was to check the correctness of the screens on the positives, as well as how well the four films fitted each other, and indeed how well the individual exposures from each of the overlay negatives onto each of the four films fitted within them. The purpose of this proof was not to check the content nor the merits of the design or colour scheme; a lot of expensive work had come to this point and to go back to the overlays, alter the images, make new negatives, re-combine to 4-colour film positive and to make another Cromalin colour proof, was not good financial practice.

As with the deep-etch colour proof the Cromalin was made as a one-off – this time as four separate operations, one from each of the four screened printing positives as opposed to one from each overlay as with a deep-etch proof.

The Cromalin base sheet of plain white plastic was covered by a taut, microscopically thin, pre-sensitised sheet of film (not dis-similar to cling-film, but thinner and more brittle) and the starting point was to punch that. With that done, the first printing positive was placed on top and the two brought together firmly in a vacuum frame. The combination was then exposed to a principally ultra-violet light. With the vacuum then released and the printing positive removed, a very fine powder the same colour as the printing ink the positive will in due course represent was dusted all over. The powder adhered where the image protected the surface during the time of exposure; elsewhere it was easily brushed away. A second laminate of taut thin film was then stretched over the top which both sealed the first layer of powder and, subsequently, would take the next to its surface. One exposure and application of coloured powder was made for each of the four process colour printing film positives. Finally, a fifth thin laminate film was stretched over the top to seal the fourth colour in place.

With the Cromalin completed, for the first time it was possible to get a reasonably accurate idea of what the final image would turn out like on paper. Whilst Cromalins did not represent precisely what a printed job will look like, they approximated the colour rendering quite closely, though, being on an opaque plastic surface, often looked a little vivid.

And so to Plate and Press

Providing the Cromalin had proved that all the colour tint combinations were correct, and that everything fitted satisfactorily, the printing films were then available for plate-making. In order to make four printing plates, there had to be four printing film positives from which to make them, and these we now had. Each of the four films was exposed to its own pre-sensitised metal printing plate; one film, one exposure, one plate each.

As explained at the beginning, the plates were (and still are today, though made quite differently now) individually fitted around the outside of their own cylinder on the printing press. The process of ‘make-ready’ then took place and involved getting each of the plates imparting their specific colour of ink in exactly the correct place on the paper, so that all four components registered precisely to one another. This took about an hour, depending on the press size. The inks also needed to be applied so that they gave an even colour consistency over the whole surface of the sheet. With this done it was then possible to run the machine at a rate of thousands of copies an hour.

In its early days, computer technology still required 4-colour films (and Cromalins) to be made and plates made from them as described above. Things have evolved apace and the advent of so called ‘disk to plate’ took over about ten years ago where the person generating the drawing now generates a high-resolution PDF from which the plates are exposed directly. This has put paid to a whole raft of individual specialist skills, photographic technologies and fine engineered equipment – all wiped out within a very short space of time.

Printing presses and their now advanced control from the computer has reduced make-ready time and increased performance. Plates used to be stored for re-use and this demanded space and maintenance (and rent from the customer for the privilege). Nowadays plates are re-cycled when the job is finished, as they received their image from a computer and not film. If a re-print is wanted it is much cheaper just to make new plates as disk space is cheap and so too are the plates relative to the past.

Conclusion

The two fields of colour-separation drawing and film repro were closely linked and heavily dependent on skilled operators. The highest quality end-product, completed at the keenest price, created in the shortest time, was always achieved where the two had an intimate understanding of each other’s methods and requirements. As with many other disciplines, there is no substitute for experience. The combination of an experienced draughtsman, and an experienced photographic camera operator was a formidable one, and could lead to some impressive results where lesser men would fail.

This essay has dealt with the general principles of manual cartography that reigned supreme until the late 1980s. There were many exceptions and alternative methods and instruments used from those described in this summary that I have not explained. I have tried to explain mainstream methodology only.

Beautifully crafted instruments, equipment and tools were consigned to the bin 20 years ago. Massively expensive precision engineered process cameras, costing eye-watering sums of money to buy and install, all went in the skip.

To prevent damage that would occur when pulled in and out, precious overlays could not be stored in flat drawers. Some had lives of many many years. Countless overlays for thousands of jobs had therefore to be stored, hanging in huge metal cabinets called ‘vertical files’ (often banks of them creating vast image libraries) with elaborate file recording and retrieval systems and card indexes. By the early 1990s you quite literally couldn't give them away, nor register punches, nor light tables. I tried, but I ended up having to pay to get them taken away.

Large store rooms full of new materials, inks, chemicals and instruments were no longer needed and nor the storemen. No-one wanted highly skilled camera operators, nor plate makers. Major film and chemical manufacturers went out of business. The inks were subsequently outlawed (not before time).

I first encountered computer generated drawings in the late 1970s and could not have imagined, firstly that they would make my skills irrelevant, and secondly, so quickly. I started using a Macintosh in 1990 and it now rules my life and I don't regret it for a second. Computers have unquestionably brought huge new possibilities that simply could not have been achieved in manual days. However, and I quote from Maya Hambly RIBA "Both the human hand and computer-aided drawing can produce abysmal or superb draughtsmanship and it is after all still the architect who should keep both under control.". I agree whole-heartedly, and the sentiment is just as applicable to my trade.

* * *

Appendix

As noted above, there were many other mainstream drawing materials and instruments in common usage. Here are just a few more for those interested.

Materials:

Permatrace was similar to Ozatex, but polished on one side. The matt drawing surface was even harder than Ozatex and in my view just not worth the bother. It had no better a drawing surface.

Ethulon was in my opinion the nicest of all to draw on. It too only had one drawing surface and needed no preparation. It was easy to draw on, did not blunt instruments, was easy to scrape ink off and revise. Though using water-based inks it was capable of reasonably black lines, though not good enough for repro and so was mainly used for creating in-house production charts that would never get printed. Sadly it had one serious drawback – you needed a clairvoyant to tell you what size it would be by the end of the week.

Instruments:

Following the ruling pen model, compasses were made in many sizes. There were also 'drop-bows' for delicate and small diameter circles and arcs. For large, and very large diameters, a 'beam compass' would be needed. These had an adjustable length horizontal bar (hence 'beam') a couple of feet in length. The longer ones (yards in length) even had small wooden wheels to help steer the pen end, which was another vertical ruling pen that could be moved along the beam to set the radius. The other end of the beam had a vertical point for the circle centre. Keeping it upright was a challenge.

Referred to earlier, ‘Rotring’ pens were also used vertically and had a tubular nozzle through which the ink came, from a plastic cylindrical reservoir. The inks had to be water based for them to work at all. Another brand was Pelikan. Both made sets of pens for different width lines and both made inks for them.

Rotring also made ‘Graphos’ pens, which had a single handle but could take interchangeable nibs for different line thicknesses. The nibs had a swivel arrangement that allowed the two part of the nib to be rotated slightly apart to insert the ink and also for cleaning. They were fiddly, came in expensive cloth-lined carrying cases and were no match for one ruling pen.

Gillott made superb freehand pens and nibs for use with almost any ink. We used them for drawing rocky coastlines, embankment symbols and tree canopy on large scale maps and all manner of other things.

Ink:
Findings on the safety of using etching inks were published in 1988. Unsurprisingly, today (2015 when this article was written) the findings caused them to be banned. See:
http://www.nicsohs.gov.uk/final_letter_from_trevor_steenson__use_of_dep_astrafoil_ink_by_ordnance_survey_employees_1968_-_1988.pdf

Equipment:
Plastic curves came in all shapes and sizes, though we frequently drew curves using tiny movements along a straight edge set square, turning it with the pen along the desired trajectory. With care, this was quicker than fiddling around never being able to find a curve the right shape.

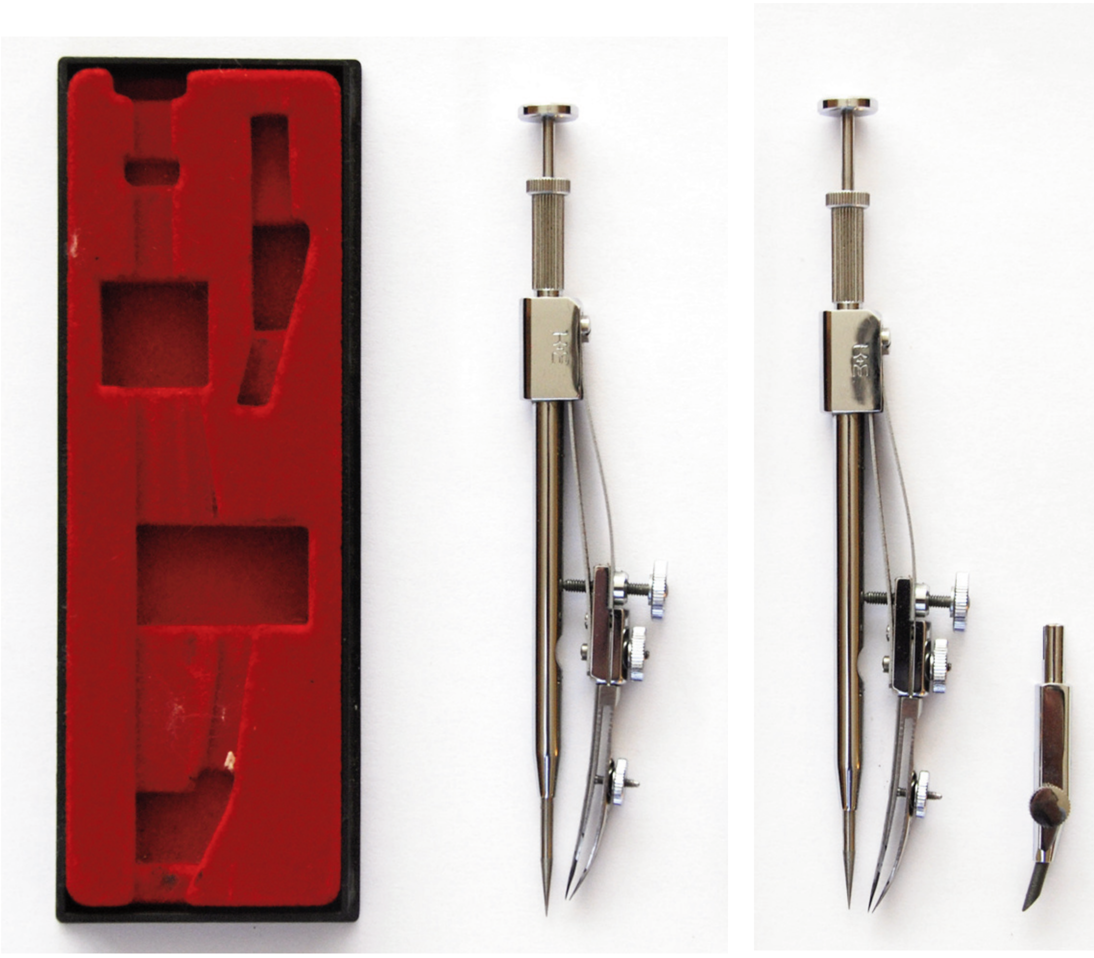
This is a ‘radius curve’ and was intended for drawing around in pencil or ink. Clearly it was not possible to draw a complete circle.

The concept may have seemed good but in practice even drawing parts of circles was far easier done using a compass adaptation of a ruling pen.

Compass adaptations for ruling pens came in a few different forms, the commonest being of a conventional adjustable two-fork construction; one having a sharp point and the other a ruling pen.

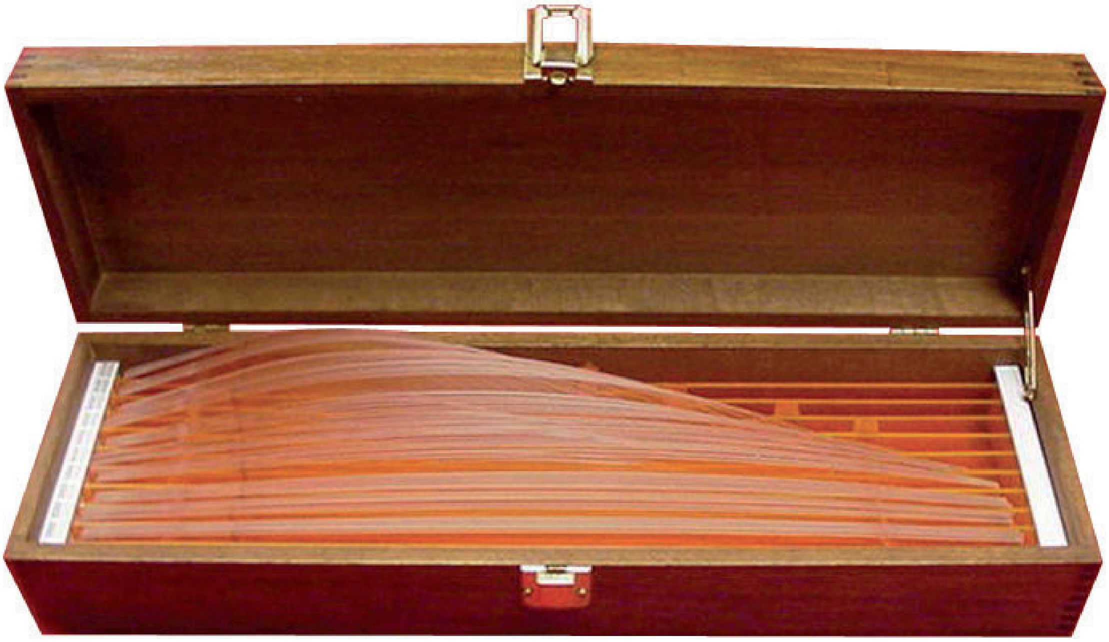
Drawing small radius circles was difficult when one fork had ink in it as it was all to easy to let the ruling pen fork touch the drawing material before having the sharp point in the right place. Remember too that the ruling pen fork really needed to be upright – yes, it wasn't easy.

The solution was to use 'drop-bows. These had a vertical pin with a circular knurled grip (disk) at the top and it floated within a tube arrangement. Near the top of the tube was a second knurled grip ring. The outer tube was connected to a spring bow with a ruling pen tip. By holding the tube grip ring between two fingers and pressing down on the central pin with another, you could lift the pen and concentrate on getting the pin in exactly the right spot on the drawing material. With the spring bow adjusted for the correct radius, the outer tube could be gently lowered to bring the ink pen into contact. The knurled ring allowed you to rotate the pen but keep the pin static and vertical, whereas conventional compasses needed the whole instrument to be rotated.



On the left alongside its storage case the pen is in its raised state; on the right it is lowered and ready to turn. Pen and pencil tips were available and interchangeable.

Railway curves were wonderful and hardly ever used. They were made from pearwood (latterly acrylic) and came in a beautifully made box as a set of about 30 pieces. Each curve was a section of a precise radius and this value was stamped onto each one. Shallow radius curves would be about 18 inches long and the smallest (tightest radius) just a few inches. They were difficult to use and, being quite thin and with a slender bevelled edge, had to be taken away from the line just drawn with great care or the ink would smudge.

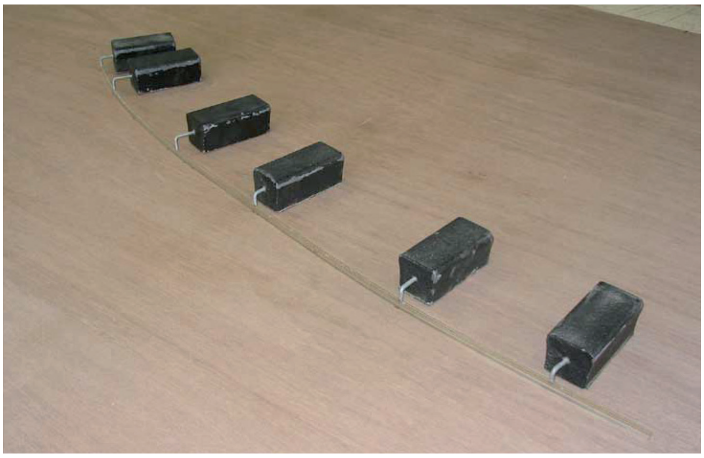


Above is a fairly typical box of wooden railway curves, though the smallest are missing from the slots on the right in this picture. Cheaper sets were latterly made from a clear acrylic and this made it possible to see the drawing beneath, which was not possible with the wooden ones.

Below is a representation of one curve. It can be seen that both edges are the same radius and not concentric, allowing either to be drawn against and produce the same result. This of course could not be achieved for the smallest radii curve.

Splines were used for very long shallow curves, and also where a slight change of curve angle or direction was needed. The wooden splines were about a quarter of an inch (about 6mm) square in cross section and many feet long. The thinness and type of wood made them quite flexible and they were held in place to create the correct curve by spline weights. These were similar in size to a computer mouse, but rectangular blocks. One short edge of the block had an inflexible metal prong sticking out, that angled down onto the top of the spline. They had to be placed at close intervals to hold the spline in place whilst it was then drawn along. These could take a long time to set up and the weights were always in the way. With a computer programme it can be done in seconds.

The same sort of thing is still used today to plan and draw curves for cutting wood panelling to shape, as seen here.



Various hard, medium and soft rubbers were used, depending on the drawing material and ink. They were not used for etching inks, where sharp flat edged blades had to be used to remove the lines by careful scraping.

On Ethulon we could use ‘plug rubbers’. They came in different hardnesses and were cylindrical and about a quarter-of-an-inch in diameter. They were used in what looked and operated like an electric drill and had variable speed settings. Too slow and not much erasing happened; too fast and the rubber could do all sort of surprising things to the material – and the user.

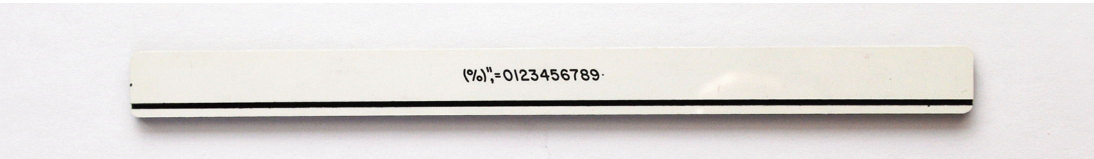
Artist’s paint brushes were commonly used with ink to fill in large areas once the outline had been produced with a pen. They didn’t last long with etching inks.

Lettering Applications:
The adhesive film made using the PMT camera had a high-tack glue on the non-image side, leaving the photographic emulsion uppermost and possible to scratch and damage. Another method of sticking complete or part words down was with ‘stripping film’, the practical use of which was the same. However, stripping film could not be made on a PMT camera and had to be made externally through a different photographic process. This time, the emulsion was on the image side of much thinner film in reverse (back to front lettering)

and the adhesive applied very thinly as hot wax on that same side, by passing it via rollers through a bath of heated wax and then onto a backing sheet. Both methods enabled small cut-out pieces (words) to be moved about on an overlay at will and also pressed down firmly with a 'burnisher' when ready. With stripping film, pressing each piece down firmly usually resulted in a little seepage round the edges and this was wiped clean using industrial cotton wool.

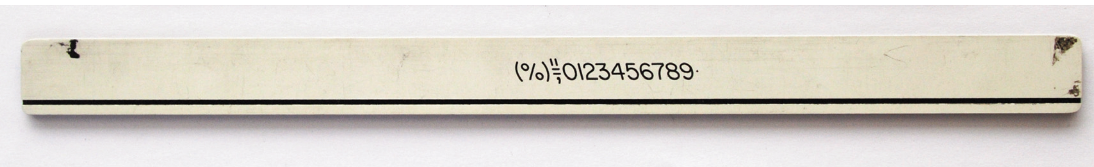
As well as sticking lettering down from adhesive films, we also used Letraset extensively for curving names, as individual letters, along roads and so on. These needed protecting on completion by the use of a clear spray coat sealant.

Lettering could also be done using stencils, most commonly 'Uno', using Rotring pens. A far more sophisticated and expensive system came from 'Leroy' where a set of plastic slides, each about nine inches long (about 230mm), were manufactured with the alphabet, numerals and punctuation grooved quite deeply on either side. A 'crab' was used and this had a pin that traced from the grooves, causing a sort of pantograph arrangement equipped with a Rotring pen to reproduce the characters. These slides (often called 'stencils') came in sets of different size alphabets and the crab could be altered, using its built-in protractor, to condense, stretch and italicize the lettering as well.



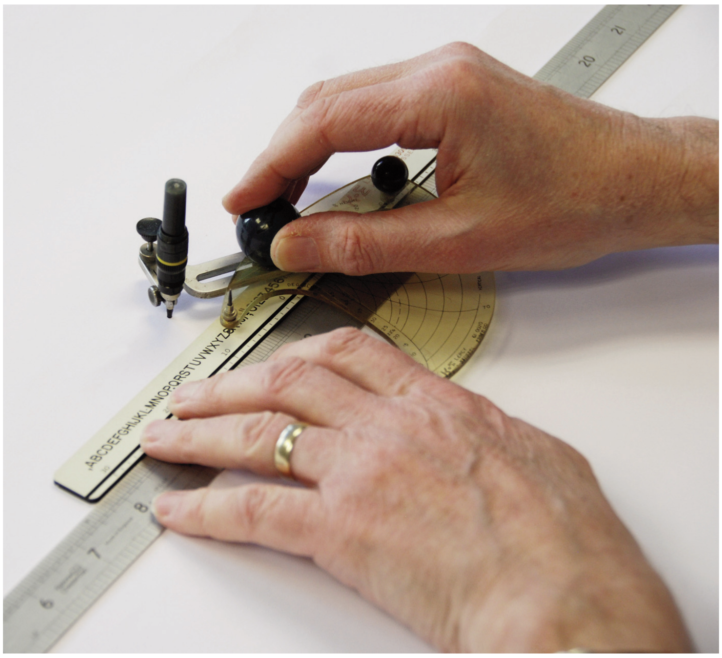
Above, both sides of the same stencil.

Below, both sides of a stencil with larger lettering. Many different sizes were available and the configuration of what was on each side varied; for example, some had the numerals and lower case on the same side.



The stencil had to be slid along straight edge that didn't move. In the photograph below it is a metal ruler (known in the trade as a 'scale'). Less experienced users would stick the scale down with tape but it was easily possible to hold it still with the little finger and slide the stencil along it using the others.

Getting the letter spacing right required skill in moving the stencil along just the right amount, having carefully lifted the tracing pin and pen upwards and out of the stencil first to move it.



The 'crab' was a very clever piece of equipment. From the top of the left-hand picture downwards: the blue disk is the top of a vertical flat ended pin that rested on the drawing surface to the same depth as the Rotring pen to keep it vertical. The pen fitted in the adjustable hole just down and to its left.

Different thickness pens could be used as larger lettering would probably require thicker characters than the smaller ones. In practice however, you could create large thin letters or small thick ones if you wanted to.

The large ball near the middle had an adjuster below and this allowed the plastic protractor to be slid along and angled. This facilitated condensing or stretching of the resulting letters and also sloping.

The smaller blue ball to the right had a flat bottomed pin for tracing the straight groove along the bottom of the slide and was fixed relative to the protractor. This kept the lettering on a straight line. Back at the top of the picture, to the left and below the pen location a small circular rivet can be seen; this had the lettering tracing pin vertically below it.

The above is far from exhaustive but covers many of the day-to-day instruments and materials used. It all seems like a different world now.