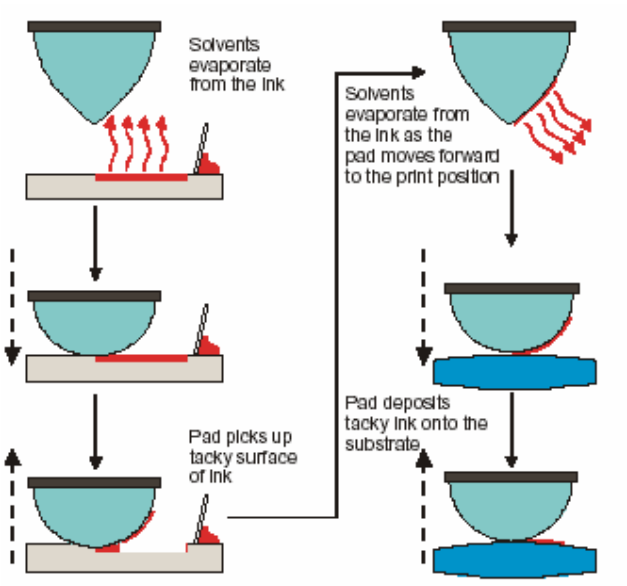
After 20 years working with pad-printing machines, I have seen many advances in the technology. Improvements in inks and pad technologies have made it more controllable. Machine design has enabled better consistency in setting and more importantly ease of adjusting each part of the cycle. The basic principles of pad printing have not changed and many of the basic problems have remained the same.

IT'S THE WEATHER

I have heard one difficulty expressed many times: "My machine prints well one day and badly the next." The sufferer will confirm they have changed nothing from the day before. Same machine settings, same pad, same ink, same thinner even the same machine operator. But in most cases, one important variable has changed - its the weather, or at least varying ambient conditions within the building.

BACK TO BASICS

To understand why varying temperature and other changes in ambient conditions can so dramatically affect print quality, it is first necessary to go back to first principles. To enable the silicone pad to pick up ink from the clich (plate) and transfer it to the substrate, very rapid changes must occur in the surface tension of the ink. These changes are caused by the evaporation of solvents. Figure 1 explains the basic process.



THIN FILM PROCESS

Pad printing is a thin film process. Starting with an etch depth of 25 Microns (1 Micron is 0.001 of a mm) about half of that ink film is picked up. Of this wet ink film 60% is solvent which evaporates leaving only 5 Microns of dried ink deposit. It is easy to see how susceptible such a thin film can be to changing temperatures, humidity levels, static charges, and even variations in airflow.

Controlling the rate of evaporation of the solvents from the ink is the key to overcoming these changes in ambient conditions. If the solvents evaporate too quickly the ink might not even pick up from the plate because it has dried in the etched portions of the plate. If the solvents evaporate too slowly, the surface of the ink may not be tacky enough to stick to the pad and lift from the etch. Both conditions, although extremes, will have the same effect - little or no ink on the pad. If solvents evaporate too quickly, ink dries and stays on the pad. If they evaporate too slowly only some ink will release from the pad onto the substrate.

ADDING SOLVENTS

Generally pad printing requires you to add solvents to your ink regularly. The length of time between additions and how much will vary depending on the ambient conditions and also the type of equipment you are using. (Machines with closed-cup inking mechanisms

reduce solvent evaporation from the ink, so they don't normally need solvents adding during the run.) If it is very warm it may be necessary to add solvents every 20 - 30 mins. Always add a measured amount - DON'T GUESS.

Here is an example of how well this philosophy can work.

A company were pad printing floppy disc shutters. They used fully automatic machines in an air conditioned environment, working a three shift system. Their output was an average of 3000 shutters per shift with an unacceptable reject rate of 30%. Obviously, something had to be done. The following routine was suggested :-

1. At the beginning of EVERY shift a new batch of ink was mixed and a specific weight of solvent added. This was a 25%/75% mix of retarder and thinner.

2. At hourly intervals the machine was stopped (regardless of the fact that the print quality was good) and a specific amount of solvent mix was added.

It took approximately two days to fully develop this working on thinner/retarder ratios, amounts of solvent to add and the length of time between additions. By strictly adhering to the procedure, production was more than quadrupled to an average of 13,000 s hutters per shift. Rejects were reduced to 2%. Both product quality and worker morale improved. The staff made further improvements in this procedure and can now regularly attain 15000 shutters per shift with less than 0.5% rejects.

USING DIFFERENT SOLVENTS

Controlling the printing process is much easier if you use the right type of solvent. Different solvents have different boiling points. The ones with a low boiling point are called FAST thinners and evaporate quickly those with high boiling points are SLOW thinners and evaporate slowly.

Suppliers normally differentiate between them by letter or more sensibly number. A No. 1 would be a fast evaporating solvent often called a thinner. A No. 9 would be a slow solvent more commonly known as a retarder.

Selecting the right speed of solvent for your application is essential. What is suitable for Cornwall in summer will not be appropriate for Shetland in winter unless printers in both regions are working in air conditioned plants with the same temperature and humidity. Your ink supplier can provide you with a range of standard solvents and will help you to select the most suitable for your climate. If you can't find the ideal standard solvent it is possible to mix your own as the floppy disc printer did. Use the fastest thinner available to you as a base and add a slower thinner before mixing with the ink. Never add a very slow solvent (retarder) directly to the ink always mix with faster solvent. This is to avoid "solvent shock" where inks look as if they have curdled and will have to be thrown away.

When mixing different solvents and inks, follow the manufacturers recommendations. Measure the components by weight and record the make up of each mixture.

Never mix solvents from different manufacturers.

CONTROLLING INK DELIVERY

Many problems printers experience can be traced back to solvent evaporation in the ink trough. One route around this problem is to control this evaporation, either by carefully metering the flow of ink to the machine or using an enclosed ink cup.

Ink pumps are okay for long runs of the same colour, but impractical for short runs. In their simplest form they are a container with a gravity feed to the ink well or cup. Care must be taken in the selection of piping. Pad printing inks contain very aggressive solvents and these will destroy most thermoplastics other than polyethylene or polypropylene, even these will deteriorate after a time. Other materials are available such as Viton (a form of synthetic rubber) or P.T.F.E. These will withstand most of t
he solvents but they can be expensive.

Gravity feeding can be somewhat intrusive. You can purchase more sophisticated ink-pumping systems from machinery suppliers or build one using peristaltic pumps. As with gravity feed selection of the tubing is important but even more so in this case as the pump operates by compressing a tube in a circular action and forcing ink along it by positive displacement. This compressing action puts a mechanical stress on the tube which if combined with attack from the solvent will cause failure in a very short period unless the correct tubing is used. Pump suppliers can offer a range of tubing one of which will suit your application. Pumps can operate at very low flows to keep your ink well topped up. Alternatively you can have a flow and return configuration which pumps the ink through the ink trough and through a reservoir as much as two litre capacity. Any solvent evaporation in the ink trough will be minimal compared to the total volume of ink in the system therefore the overall ink solvent balance is maintained.

Solvent feeding systems can work on a similar principle to ink feeding systems. Gravity feed has been used reasonably successfully. Powered hypodermic syringes have been tried but the solvents destroy them over a period. Pumping is best but even with this t here are problems with mixing the solvents into the inks. The position that the solvent is fed into the ink trough is important and some machinery suppliers provide modified spatulas that assist in the mixing of solvent into the ink.

Several dosing systems are available commercially, or you can build one using a peristaltic pump.

Points to look for in a pumping system include flow control, solvent resistant tubing materials and ease of cleaning.

ULTRA VIOLET CURING INK AND THERMOPLASTIC INK TECHNOLOGY

Several ink manufacturers are investigating the use of U.V. curing inks in the pad printing process. The reasons being:-

- To get away from the environmental problems of using solvents in the process. Maybe a case of the lesser of two evils considering the reactive monomers and other chemicals in U.V. Curing ink.

- To make the process more stable in varying ambient conditions.

- To give consistent quality even with intermittent printing.

So far one of the methods of achieving this is to simply add small amounts of solvents to U. V. inks. 10 to 20%. When this is compared to the 60 to 70% contained in conventional ink there are obviously considerable reductions in VOC's (Volatile Organic Compounds).

The other method is to treat it as a thermoplastic ink as is currently used in glass and ceramic printing systems. With thermoplastic ink the pigment is suspended in a temperature sensitive medium. At room temperature this looks and feels like hard candle wax. When elevated to approximately 80 degrees centigrade it becomes fluid and behaves like a conventional ink. The ink trough and the plate are heated to a thermostatically controlled elevated temperature. The machine cycles as normal. The cooling effect of the pad picks the ink out of the etching and the cooling of the ink on the pad causes the outer surface of the ink to become tacky and when in contact with the substrate to peel of the pad. This method transfers a large proportion of the ink from the etched plate to the substrate. Pigments and U.V. resins are suspended in a thermoplastic medium for this process to work.

With both ink systems once the ink is on the item it has to be passed through an Ultra Violet Curing tunnel. Here the ink cures instantly and the item can be processed. The problems involved in U.V. ink technology is another story that has been written of in great length elsewhere. These are not yet production systems and developments are continuing.

MACHINES WITH CLOSED CUP INK CONTAINERS

Printing machines using this type of inking mechanism have been available for several years. They have become much more popular with the use of pad printing in line on moulding machines and the need to reduce the amount of solvents in the workroom.

The stability of inks in these machines is much better than in open trough machines. They are still affected by ambient conditions at the pick up and lay down of ink.

Running the machine faster is possible as you can use very fast solvents which in an open ink trough would evaporate far too quickly to be practical.

The use of two component ink, particularly isocyanate based systems, is not recommended. These will gel in the cup if not agitated and their effective operating period is much reduced. This can come down from 8 hours to as little as 2 hours.

Taking these reservations into account the system goes some way towards the aim of reducing the variables in the process and allowing intermittent operation of the machine. I would recommend them for many applications.

CONTROLLING TEMPERATURE AND AIR FLOW

The more stable the environment, the more effectively you can control the process. This may seem quite basic, I find that many common problems solve themselves when a few simple rules are followed.

An obvious solution to controlling ambient temperature is to operate your printing machine in an air conditioned room. Other measures to control temperature may not be quite so evident. The machine should be kept out of draughts. Keep away from direct sunlight. Shield from entrances or exits of dryers. Don't put the machine in a part of the plant where there are large temperature variations whether or not it is air conditioned.

THE USE OF HAIR DRYERS

If a controlled environment is not practical it is possible to modify the ambient conditions at the point of print. An essential tool in every experienced pad printers' cupboard is a variable speed/temperature air blower more commonly known as a "Hair Drier". This makes it possible to alter the conditions right at the machine. When temperatures are low and the solvent in the ink is not evaporating quickly enough application of either hot or cold air to the pad and substrate will alter the conditions to enable printing to take place. Sometimes it is only necessary to blow air onto the pad or the substrate, experimentation will determine speed temperature and direction of air flow. Normally this procedure can be stopped once the ambient conditions have returned to normal.

OTHER EFFECTS OF VARYING TEMPERATURES

Consider the role that temperature plays outside the printing process.

For example:

Storage of components prior to and after printing is very important. Components are often stored in large warehouses prior to printing.

These warehouses are very rarely heated and in winter often reach freezing. When you bring these components into your heated print area the difference in surface temperature is dramatic and the component gets a very fine film of condensation on the surface, (generally this cannot be seen with the naked eye). Under such conditions you will find it difficult to obtain good prints and also it is unlikely that the ink will adhere properly. To overcome this problem it will be necessary to bring the components into the print area several hours in advance to allow them to reach a stable temperature.

Product storage immediately after printing can be affected by low temperatures. If you use a two part ink system do not let the temperature at which the components are stored drop below 15^{o}C until they have fully cured, (if you are air drying this can be up to 4 days+). The result of storing below 15^{o}C is that the ink will stop curing at that point. You **cannot** reinstate the curing process once this has happened.

To control airflow, keep the printing machine away from draughts. For example don't position it underneath an air conditioning duct. Too much air flow round a machine will promote faster solvent evaporation. A combination of high temperature and high airflow will increase the effect. The accelerate irregular ink drying will result in ink remaining in the etched plate and/or on the pad, causing inconsistent ink deposits or missed prints.

Not only will draughts or circulating air cause solvent evaporation, but they can also cause dust contamination problems, not necessarily prior to printing but afterwards particularly if you are printing relatively large areas or printing several times (to obtain a dense print). Because of the nature of the products we are printing they generally come packed into cardboard boxes which of course generate dust. The dust in the atmosphere is attracted to the tacky surface of the printed parts and settles onto the print. The more air flow round the printing machine the greater the chance of dust contamination. Short of having clean room conditions, good house keeping is the only way to overcome this problem. Ideally, vacuum the floors, sweeping will only circulate the dust again. If possible avoid using cardboard boxes or at least line them with polythene bags. Wipe down all surfaces using a damp cloth.

CONTROLLING HUMIDITY AND STATIC

Many traditional screen printers have been known to boil a kettle underneath the screen printing bed - not just to make coffee but also to produce water vapour on those dry crisp days when static as a problem. Dry air will not earth the static electricity generated in most printing processes. Tampo printing generates large amounts of static electricity, particularly with silicone rubber pads. I have measured this and have found levels in excess of 20,000 volts! Link this with static electricity inherent in plastic moulded components and you have the potential for real problems.

Static is normally demonstrated by feathering of the print. Don't confuse this with a plate that is etched too deeply, which can give a similar effect. The cure is not always obvious. The simplest solution is to reduce the amount of static electricity generated by slowing down the machine, particularly pick up and print strokes. People have tried earthing the pads and jigs. This helps but is not always the solution. Others use the boiling kettle. Anti static solutions can help but sometimes disturb the chemistry of the inks. The only real answer is to air condition and humidify the environment.

Humidifiers and dehumidifiers are a solution to some problems but they must be self regulating otherwise you will run into the same problems of swings in ambient conditions.

Static control is a huge subject and static elimination devices themselves vary in effectiveness depending on ambient conditions. These devices are intended to create a conductive (ionised) environment.

Ionising bar electrodes work best with film or flat surfaces that are passed under them. The distance between the surface and the electrode is critical as a stationary static field is created by these devices.

The preferable method is to use the Air Gun system where a low velocity flow of air passes over electrodes, this air will carry the conductive ions over a distance of up to 3 feet. This system stands a better chance of discharging the static from the silicone pad and the plastic component. The Air Gun can be placed before the print station with either higher velocity air that blows the dust off the component or in a special configuration incorporated in a vacuum cleaning device. High velocity air should not be aimed at the pad or plate unless you wish to speed up evaporation of the solvent. Higher velocity air can be self defeating as it can lift dust into the air which lands back on the component. Good housekeeping that reduces dust in the environment is essential.

Static devices will help reduce the classic feathering but care must be taken in their application and experimentation is often necessary to arrive at a solution. Good equipment suppliers will be pleased to lend you equipment and offer advice. Do not expect them to be a panacea for all conditions. First of all make sure that the plate is not etched to deeply or the ink is too thick. Good process control saves money all along the line

CONTROLLING MACHINE SPEED

Another troubleshooting step that some printers overlook is how fast the machine operates. Adjusting the speed of the machine will give the solvent more or less time to evaporate which enables you to address changing ambient conditions. Slowing the machine will also reduce static generated by the pad.

The most common fault demonstrated regarding machine speed is that people run the machine too quickly. Slowing it down can often improve the quality of print and reduce rejects. This enables more ink to be lifted from the plate and laid down. Also machine vibration is reduced and the operator can monitor quality more easily.

Remember it is the number of good quality items printed not the cycle time of the machine that is important.

Probably the most important aspect of a machine cycle is the pick up and lay down of ink. I would not consider buying a machine that did not have the facility of adjusting what is known as the "dwell" this feature gives you the ability to fine tune the printing process where the roll on and roll off of the pad determines to some extent the amount of ink that is transferred. Machines without it still work quite adequately but when you are up against it with quality while still maintaining the overall machine speed this dwell adjustment can be so useful.

CONTROLLING THE VARIABLES

We have looked at how ambient conditions can effect print quality, these are not the only variables in the pad printing process.

The key to successful Pad Printing is to control the variables. If this is done Pad Printing can be treated as an engineering process not a "Black Art". The use of a Production Control Card or similar (See Figure 2) will go a long way to reducing these variables whatever the ambient conditions.

A tip to finish on :- whenever you are solving problems NEVER make more than one change at a time, ALWAYS keep notes on what adjustments you are making, keep samples and number them in line with your notes so that you can see and refer back to points at which you have achieved an improvement or the print deteriorated.

[See next page for Production Control Card example]

FIGURE 2 PRODUCTION CONTROL CARD

Product		PHOTOGRAPH OF THE PRINTED COMPONENT
Part No		
Description of Print		
Design No		
Material		

PRODUCTION DETAIL			
Plate Ident. No			
Ink Type			
Ink Colour			
Ink Ref			
Ink Weight			
Catalyst			
Catalyst Weight			
Ink/Cat Ratio			
Thinner			
Retarder			
Thinner/Retarder Ratio			
Additional Additives			
Pad Ref			
Pad Hardness			
Blade Type			
Rate/Hr			
Sample No			
Approval Internal			
Approval Customer			
Packing			
Test Procedures			
Sampling Levels			
Revisions			
Pre Treatment	Flaming	Solvent Wipe	Corona
Post Treatment	Heat	Flaming	Air Dry
Setting Aids			

PLATE AND ARTWORK	
Artwork Ref	
Positive Ref	
Date Ordered	
Size	
(Un)Screened?	
Etch Depth	
Steel or polymer	
Date Rec'd	
Checked	
Comments	

HOW TO HANDLE TEMPERATURE VARIATIONS

TOO HOT

In a warm atmosphere, solvents in the ink evaporate very quickly. The result is that the ink dries on the pad and is not transferred or is only partially transferred leaving a patchy print. To resolve this problem you could:-

- Speed up the forward travel of the pad stroke;
- Use a thinner retarder mix, (I always start with a 25% retarder to 75% thinner mix, then modify the ratio according to the print results);
- Bring down the ambient temperature, (I know this sounds easier said than done but could you move the printer away from a window with direct sunshine coming in)?

TOO COLD

If the atmosphere is too cold you may get a similar effect to (a), that is a patchy print because the solvents are not evaporating quickly enough. The result is that the surface of the ink does not dry quickly enough prior to transfer from the pad causing patchy prints; occasional prints with feathering; prints which vary in density; on multi- colour printing this may cause the next pad to actually lift some of the ink from the printed component which is then transferred back onto the plate of the next colour, this over a period of time will actually cause the inks in the trough to change colour.

To resolve this problem you could:-

- Slow down the forward travel of the pad stroke;
- Select a faster drying thinner;
- Use a hairdryer, normally pointed at the pad as it travels forward to speed up the evaporation of the solvent;
- Raise the ambient temperature by increasing the heating locally.

But how do I know if the ink is drying too quickly or not quickly enough I hear you ask ? The easiest way to check is to gently rub the tip of your finger over the pad after its print stroke is finished. If the ink is drying too quickly there will be no ink, if the ink is not drying quickly enough then there will be a smudge of ink there. (Of course you will be wearing protective gloves when you do this, ink and solvent contact with the skin must always be kept to an absolute minimum).