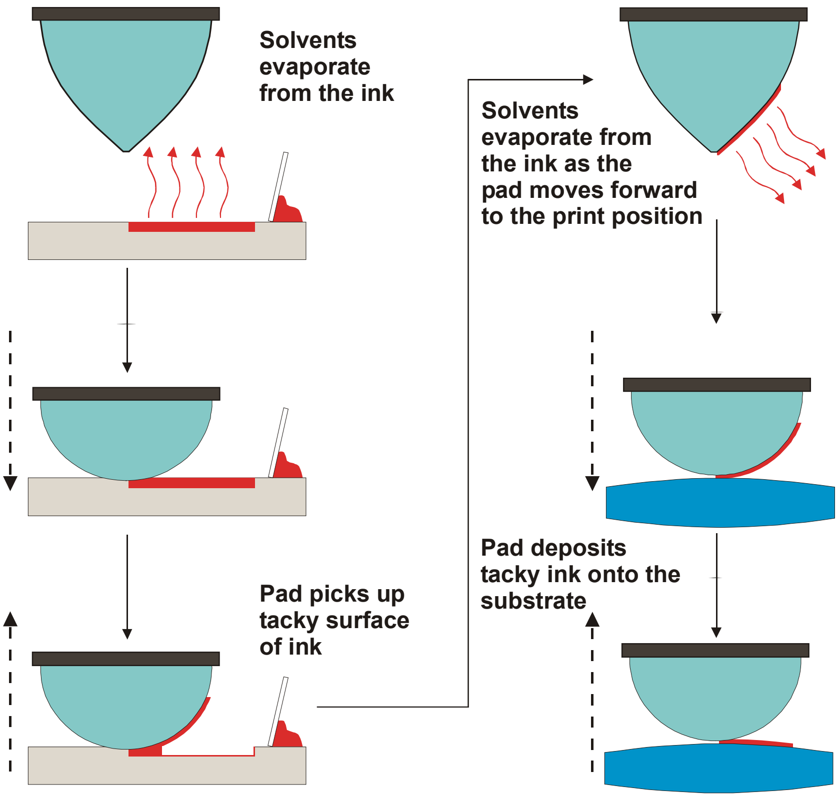
After working with pad printing machines for 20 years. I've seen many improvements in the technology. Upgrades in inks and pads have helped make the process more controllable. Better machine design has enabled better consistency in setting and (more importantly) easy adjustment of each phase of the print cycle. Yet the basic principles of pad printing have remained the same. So have the basic problems.

I've heard one difficulty expressed time and again: "My machine prints well one day and badly the next". The sufferer will confirm that nothing has been changed from the day before – same machine settings, same pad, same ink, same thinner, and even the same press operator. But in most cases, one important variable *has* changed – it's the weather, or at least the ambient conditions within the plant.

To understand why temperature swings and other changes in ambient conditions can have a drastic effect on the quality of your prints, you must go back to the basic principles of pad printing. In order for the silicone pad to pick up the ink from the cliché and deposit it on the substrate, very rapid changes must occur in the surface tension of the ink caused by the evaporation of solvents (Figure 1). Moreover, pad printing is a thin film process. It starts with an etch depth in the cliché of just 25 microns, and only about half of that ink film is picked up by the pad. Of this wet ink, 60% is a solvent that evaporates, leaving only a 4 - 6 microns dry ink deposit. You can easily see why such a thin ink film is so susceptible to changing temperatures, humidity levels, static charges, and even variations in airflow.

FIGURE 1

Principles of Pad Printing



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Controlling the rate that solvents evaporate 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 cliché 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. Taken to extremes, both conditions have the same effect – little or no ink on the pad. Once ink is on the pad, the effects are similar. If the solvents evaporate too quickly, the ink dries and stays on the pad. If they evaporate too slowly, only some of the ink will release from the pad onto the substrate.

ADDING SOLVENTS

In most cases, pad printing requires you to add solvents to your ink regularly. How much you add and how often will vary depending on the ambient conditions and also the type of equipment you are using. (Closed cup presses, for example, prevent solvents from evaporating, so they generally don't require solvents to be added so frequently during the run). In a warm environment, you may need to add solvents every 20-30 minutes. Always add a measured amount – *don't guess!*

Here's an example that shows how well this philosophy can work. The company in question was pad printing floppy disk shutters. They used fully automatic machines in an air conditioned environment, operating them over three shifts. Their output averaged 3000 shutters per shift with an alarming reject rate of 30%. Obviously, something had to be done. This is the procedure they tried:

1) At the beginning of *every* shift, a new batch of ink was mixed and a specific weight of solvent was added (a 25/75% mix of retarder and thinner).
2) At hourly intervals, each press was stopped (even if the print quality was still good) and a specific amount of the solvent blend was added to the ink well.

It took the shop approximately two days to find the correct thinner/retarder ratios, amounts of solvents to add, and the length of time between additions. But by strictly adhering to the procedure, production more than quadrupled to an average of 13,000 shutters per shift. Rejects were reduced to 2%. Both product quality and worker morale improved. The staff made further improvements to this procedure and can now regularly attain 15,000 shutters per shift with less than 0.5% rejects.

USING DIFFERENT SOLVENTS

You can go a long way towards controlling the printing process by using the right type of solvent. Different solvents have different boiling points. Ones with low boiling points are called *fast* and evaporate quickly; those with high boiling points are called *slow* and evaporate slowly. Suppliers normally differentiate between them by letters or numbers. For example, a No 1 would be a fast solvent (known as a *thinner*), while a No 9 would be a slow solvent (more commonly called a *retarder*).

Selecting the right solvent speed for your application is essential. What is suitable for New Mexico in the summer will not be appropriate for UK in the winter, unless printers in both regions are working in air conditioned plants with the same temperature and humidity. Your ink supplier offers a range of standard solvents and will help you select the most suitable one for your climate.

If you can't find the ideal solvent, it is possible to mix your own. As the floppy disk printer did. Use the fastest thinner offered by your ink manufacturer as a base, and then add a slower solvent before mixing with the ink. Never add a very slow retarder directly to the ink, or you will experience "solvent shock", where the ink looks as if it has curdled and will have to be thrown away. Always mix the retarder with a faster thinner first.

When mixing different solvents and inks, follow the manufacturer's recommendations. Measure the components by weight and record the makeup of each mixture you make. And above all, nev*er mix solvents from different manufacturers*.

CONTROLLING INK DELIVERY

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

Ink pumps are okay for long runs of the same colour, but are impractical for short runs. In their simplest form, ink pumps are simply containers that feed by gravity into the ink well or cup. Take care in selecting the piping for such a system. Pad printing inks contain very aggressive solvents that will destroy most plastics other than polyethylene or polypropylene. Even these will deteriorate over time. Other materials such as Viton* (a form of synthetic rubber) are available that will withstand most solvents, although they can be expensive.

Gravity feeding can be somewhat intrusive. You can purchase more sophisticated ink pumping systems from equipment suppliers or build one using peristaltic pumps. As with gravity feed systems, selection of the tubing is important, but even more so since the pumps operate by compressing a tube in a circular action and forcing the ink along it through positive displacement. This compressing action puts a mechanical stress on the tube that, combined with the attack from the solvents, can cause failure in a very short period of time unless you use the correct tubing. Pump suppliers offer a range of tubing materials and can suggest the best one for your needs.

You can operate an ink pump at a very low flow rate to keep your ink well topped up, or you can set it up in a flow-and-return configuration, where ink is pumped through the ink well into a reservoir with a capacity up to 2.5 litres. Any solvent evaporation that takes place in the ink well will be minimal compared to the total volume of ink in the system, so the overall ink/solvent balance will be maintained.

Solvent feeding systems work on a similar principle. Gravity-feed systems have been used with reasonable success, while powered hypodermic syringes have been tried with little luck because the solvents destroy them gradually. Pumping systems work best, but must provide a means to mix the solvent into the ink. The position in which the solvent is fed into the ink well is very important. Some suppliers provide systems with modified spatulas that help mix the solvent into the ink.

Several solvent “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, tubing materials (again, solvent resistance is crucial), and ease of cleaning.

Presses with closed cup ink containers have been available for several years and have become much more popular for in-line plastic moulding applications and in areas where VOC emissions are a concern. Ink stability in these presses is much better than in models with open ink wells, although they are affected by ambient conditions when the pad picks up and deposits the ink. These presses also allow faster printing speeds because you can use very fast solvents that would evaporate far too quickly in an open ink well. However, the use of two component inks, particularly isocyanate-based ones is not recommended with these presses. Such inks will gel in the cup if not agitated and can reduce the effective operating period for the press from 8 hours to as little as 2 hours.

Controlling Temperature and Airflow

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

To control temperature, the obvious solution is to operate your press in an air conditioned room. But other measures to control temperature may not be quite as evident. For example, keep your presses away from direct sunlight. Don’t put them too close to the entrances of exits of conveyorised dryers. Don’t put them in any area of your plant subject to wide swings in temperature, whether or not they are air conditioned.

If a controlled temperature environment is beyond your reach, other options are available. An essential tool in every experienced pads printer’s cupboard is a variable speed, variable temperature air blower (You and I call them *hair dryers*!). When temperatures are too low and solvent in the ink is not evaporating quickly enough, you’ll find that blowing hot or even cold air from the hair dryer onto the pad or substrate will enable printing to take place. By experimenting you can determine the proper speed, temperature and direction of the airflow. Normally, you can stop this procedure once ambient temperatures have returned to normal.

Also, consider the role that temperature plays outside of the printing process. For example, storage of substrates before and after printing is very important. Prior to printing, substrates are often stored in large warehouses that are very rarely heated and may reach freezing temperatures. When you bring these parts into a heated plant during the winter, the difference in surface temperature is dramatic. On the substrate surface, a very fine film of condensation can form that generally cannot be seen by the naked eye. Under such conditions, you will find it difficult to obtain a good print or acceptable ink adhesion. To prevent this, bring the substrates into the print room several hours in advance to allow them to reach a stable temperature.

Product storage immediately after printing can also be affected by low temperatures. If you use a two part ink system, don't let the printed parts drop below 59°F (15°C) until they have fully cured, which can take up to four days or longer if you are air drying them. If the parts fall below 59°F (15°C), the ink will stop curing and you cannot reverse the problem.

To control airflow, keep the press away from drafts. For example, don't position it underneath an air conditioning duct. Too much air movement around the press will promote faster solvent evaporation. A combination of high temperature and high airflow will increase the effect. The accelerated, irregular ink drying will result in ink remaining in the cliché and/or on the pad, causing inconsistent ink deposits or missed prints.

Not only will drafts or recirculating air cause faster solvent evaporation, but they can also create contamination problems, particularly if you are printing relatively large images or repeating the print stoke several times to increase opacity. Many of the substrates that pad printers use are packed in cardboard containers, which, of course, generate dust when they are opened and handled. Dust in your shop will be attracted to the tacky surface of the printed parts. The greater the airflow around the press, the greater the chance of dust contamination.

Short of clean-room measures, the only way to overcome this problem is through good housekeeping. Vacuum the floors instead of sweeping them because brooms only recirculate the dust. Do it at night after production has stopped. If possible, avoid bringing cardboard boxes into the production area, or at least line them with polyethylene 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 press – not to make coffee, but to produce water vapour on those dry, crisp days when static is a problem. Low humidity can cause problems in most printing processes, and pad printing generates very large amounts of static electricity because of the silicone rubber pads. Using a static meter, I've taken readings of over 20,000 volts in some shops. Add to this the static electricity inherent in plastic moulded substrates, which are so common to pad printing, and you have the potential for real problems.

You can usually spot a static problem by feathering on the print. Don't confuse this with a plate that is etched too deeply, which can cause similar print defects. Unfortunately, this problem can be more difficult to solve and diagnose. The simplest solution is to reduce the amount of static electricity generated by slowing the press down, particularly the ink pickup and laydown. People have tried earthing the pads and jigs, which helps but is not always the solution. Others use the boiling kettle or a stand alone humidifier by the press (If you use a humidifier, be sure it is self-regulating and can maintain a given humidity level, or you'll run into the same problems you will any time ambient conditions fluctuate).

Static elimination solutions and devices vary in effectiveness. Applying antistatic solutions to the substrates can help, but they sometimes disturb the chemistry of the inks. Since pad printing often involves three dimensional parts, stationary ionising bar electrodes often aren't effective because the distance between the substrate surface and the electrode is critical. These devices generate a stationary static field and work best with films or other flat surfaces.

In pad printing, "air gun" ionising systems are preferable. With these systems, low velocity airflow passes over the electrodes, carrying the conductive ions over a distance up to 3 feet. This system stands a better chance of discharging static from the silicone pad and then substrate. You can place the air gun before the print station, either with higher velocity air that blows dust off the substrate or a special configuration vacuum cleaning device. Don't aim the high velocity air at the pad or cliché unless you wish to speed up solvent evaporation. Also keep in mind that high velocity air can be self defeating in that it can lift dust into the air that will land back on the substrate later.

Antistatic devices will reduce the classic feathering defects, but be careful when using them. You'll often need to experiment with them to find the best solution. Don't expect them to be panaceas for all of your difficulties. Before you invest a lot of money in one, make sure your clichés aren't etched too deeply or your ink isn't too thick.

Controlling Machine Speed

Another troubleshooting step that some printers overlook is how fast the press operates. By adjusting the speed of the machine, you will give the solvent more or less time to evaporate, which allows you to address changes in shop conditions. Slowing the press down will also reduce the amount of static generated by the pad.

The most common mistake people make is running their presses too quickly. Slowing them down can often improve the print quality and reduce rejects. Slow speeds allow more ink to be lifted from the cliché and deposited on the substrate. Also, machine vibration is reduced and the operator can monitor quality more easily. Remember, it's the number of good quality items you print that matters, not the cycle time of the machine.

The most important parts of the press cycle to control are the pickup and laydown of ink. I would not consider buying an automatic machine that did not allow me to adjust the speed of these two steps (known as the dwell time). This feature allows you to fine tune the printing process because the way the pad rolls on and off the cliché and substrate determine, to some extent, the amount of ink that is transferred. You are trying to achieve a smooth, rolling action of the pad, and "smooth" generally means "slow". Machines without a dwell adjustment still work quite adequately, but the feature can be exceptionally useful when you face a quality problem and need to maintain overall machine speed.

CONTROLLING THE VARIABLES

We've looked at how ambient conditions can affect your print quality, but these aren't the only variables in the pad printing process. The key to successful pad printing is to control all of the variables. If you can do this, you can treat pad printing as an engineering process instead of black magic.

Here are two more tips to finish with. First, a production control card like the one shown in Figure 2 will go a long way to minimize these variables, whatever the ambient conditions are in our plant. Second, whenever you are troubleshooting a quality problem, *never* make more than one change at a time and *always* keep notes on what adjustments you have made. Keep samples and number them in coordination with your notes so you can refer back to see which changes improved print quality and which ones caused it to deteriorate.

FIGURE 2

Production Control Card

Production	____________	Photo of the printed component	
Part number	____________		
Description of print	____________		
Design number	____________		
Material	____________		
Production details	____________		
Plate identification number	____________	Ink colour	____________
Ink type	____________	Weight	____________
Ink reference	____________	Weight	____________
Catalyst	____________		
Ink/catalyst ratio	____________		
Thinner	____________		
Retarder	____________	Thinner/retarder ratio	____________
Additional additives	____________		
Pad reference	____________	Hardness	____________
Blade Type	____________		
Rate/hr	____________		
Sample number	____________	Internal approval	____________
Customer approval	____________		
Setting aids	____________		
Packing	____________		
Test procedures	____________		
Sampling levels	____________	Revision	____________
Pretreatment	Flame	Solvent wipe	Corona
Post-treatment	Heat	Flame	Air dry
Plate and artwork			

Setting aids

____
____
____
____

Artwork reference	____________	Positive reference	____________
Date ordered	____________	Size	____________
Screened/unscreened	____________	Etch depth	____________
Steel or polymer	____________	Date received	____________
Checked	____________	Comments	____________

Note: Ink, Pad and Positive references are categories developed to work with an internally developed system that uses numbers for ink type, pad shape and size, and art file. Modify this chart according to the systems you use in your shop.