Product User Guide

PFI-722 Conductive Flexographic Ink

Product Description

PFI-722 is an aqueous flexographically printable conductive ink containing PChem's proprietary silver nanoparticles. PFI-722 has been specifically formulated for high conductivity and minimal cured film thicknesses. This allows equivalent sheet resistances with less material usage compared to competitive inks.

Key Benefits

- Fast curing at low temperatures suitable for reel to reel processing on PET films
- Excellent conductivity and thin cured film thicknesses for material cost savings
- Good printability, with features less than 25 microns possible
- Good flexibility and crease resistance
- Good adhesion to print treated polyester films
- Minimal VOC's
- Easy cleanup with soap and water

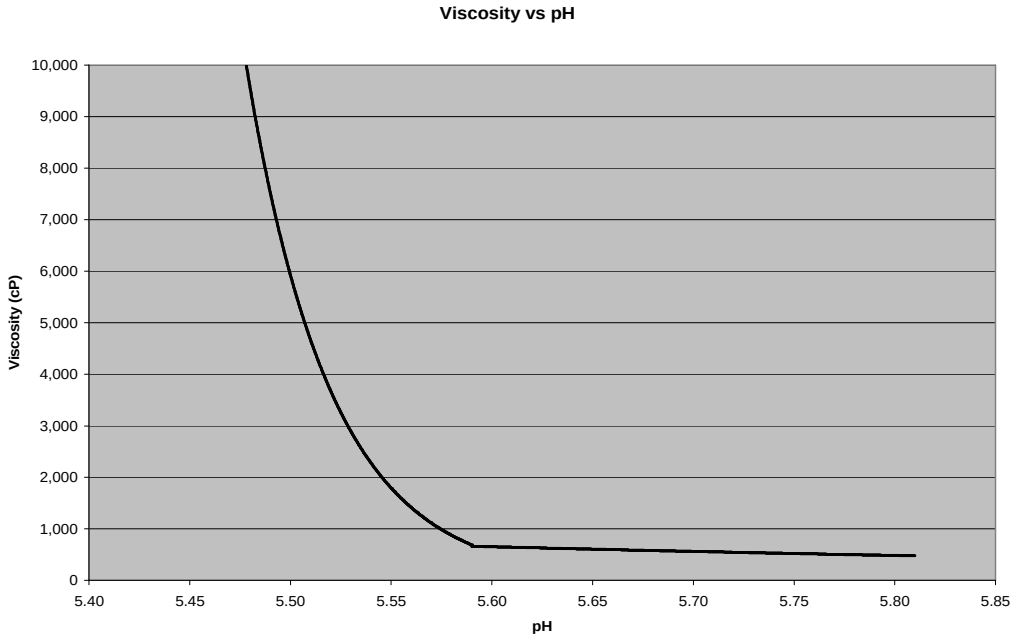
Physical Properties

Silver Content (wt%)	60% (±2%)
Density (wet)	2.2 g/ml (17.53 lb/gallon)
Viscosity @10s-1	350-650 cP
Viscosity @1s-1	1000-2500 cP
pH	5.85 (±.05)
Volume Resistivity	5-7 μΩ-cm (2.0-2.8 mΩ/sq/mil)
Printed Sheet Resistance	60 mΩ/sq at 1 micron (typical DFT)
Coverage	120 m^2/kg at 1 micron (typical DFT)
Shelf Life	3 months, >6 months with pH adjustment and refrigerator storage

Storage and Handling

The ink container should be sealed when not in use. The ink should be stored in a cool environment. During storage, the pH of the ink should be monitored monthly to ensure it does not drop below 5.65. If the pH drops below this value, it can be adjusted back upwards with a dilute ammonia solution. Refrigeration will extend the time the ink can last without pH adjustment. Typical storage times without adjustment can be on the order of several months, depending on ambient temperature and how well the container is sealed. Ink that is used frequently, or has spent a long time on press will need to have its pH checked more frequently. With proper maintenance of the ink's pH, a shelf life greater than 6 months is possible.

If no pH meter is available, then the pH of the ink can be estimated by its viscosity. The viscosity of the ink will slowly increase at it loses ammonia, until it reaches approximately pH 5.60, where its rate of increase rapidly accelerates. If the ink has thickened noticeably since the last time it was used, it almost certainly needs a pH adjustment.



pH Adjustment

The pH of our ink drops gradually during storage, and more rapidly during printing. Eventually, the pH of the ink will need to be raised by adding aqueous ammonia. The time to adjust can be determined by either direct pH measurements or by noting the ink's viscosity. The ink's viscosity increases gradually as pH drops towards 5.60 and then rapidly thereafter. If the ink looks like black mud, then it has almost certainly dropped below a pH of 5.60 and needs to be adjusted upward. Typically, an ink can sit on the shelf for several months or run on a press for 4-16 hours before needing a pH adjustment. Please contact PChem directly for more detailed information.

Two different pH adjusting solutions are recommended by PChem, 2.5% and 0.5% solution (per NH_3). Any solution higher than 10% can possibly shock the system and is not recommended. The choice of adjusting solution to use will depend on the history of the ink. If the ink has been mostly in storage, less water evaporation will have occurred and the 2.5% adjuster is more appropriate. If the ink has been used on press multiple times, significant water loss has likely occurred. Use of 0.5% ammonia is recommended in this case.

As a general guideline, the following formulae can be applied:

Formula 1: A 1% addition of 2.5% ammonia will raise the ink's pH by 0.10.

Formula 2: A 1% addition of 0.5% ammonia will raise the ink's pH by 0.02.

For example, if 1Kg of an ink has dropped from the desired pH of 5.85 down to 5.65, we could either add 20g of 2.5% ammonia, or 100g of 0.5% ammonia to restore it to its optimal condition. The ammonia solution should be slowly stirred into the ink in a well ventilated area. Please see the ammonia MSDS for details. We recommend that the pH or viscosity be checked at least once during the addition to verify the calculations, with continuous checking preferred (see below). If no pH meter is available, then we recommend targeting a series of 0.05 pH unit adjustments, with qualitative observations after each addition. It is rare that the pH will have fallen below 5.50, so no more than 0.25 units should ever be adjusted upwards without a pH meter.

The following procedure is recommended as a means to adjust pH:

Equipment and Materials Required:
pH meter with at least two decimals precision
Double junction Ag/AgCl (e.g. Hanna FC-210) or ISFET probe
Mixer or continuous pumping of the ink (i.e. peristaltic pump)
PChem pH adjuster solution (or ammonium hydroxide solution)
Pipette or syringe to carefully meter addition
Soapy water and a toothbrush for cleaning the pH probe

Warning: adjustment of the ink pH past the upper specified value of pH 6.0 may result in irreversible damage to the ink. Mixing of the ink should always be used during pH measurement and adjustment.

Procedure:

1. Calibrate pH meter per manufacturer's instructions with standard pH solutions. Use pH 7.0 or pH 4.0 & 7.0 standards depending on if a 1 or 2 point calibration is required.
2. Begin mixing or pumping the ink with overhead stirrer, peristaltic pump, etc.
3. Insert pH electrode into ink in a region where it appears there is some flow occurring and secure the probe if possible.
4. Dispense some of the pH adjusting solution into a pipette, syringe, etc. such that the amount of solution can be carefully metered into the ink.
5. Add the solution slowly into the ink while measuring the pH with meter.
6. Be sure the pH electrode sensor portion is submersed in ink while adjustment is being made.

7. Monitor the pH change with addition as it may require seconds to minutes for the adjuster solution to equilibrate with the ink depending on the mixing being used.
8. Clean the pH probe with soapy water and a toothbrush. Rinse with distilled or deionized water. If improperly cleaned, silver can build up in the porous membranes and ruin the probe.

Notes:
1.) The amount of adjustment and frequency required will depend on the equipment used as well as the environmental conditions in the press room.
2.) If a pH meter is not readily available then the solution should be added slowly drop wise to the ink allowing it to effectively mix with the ink while observing the viscosity and appearance of the ink.

Viscosity Adjustment & Solids Determination

Since viscosity and pH are so closely linked with this ink, the first way to approach viscosity control is by adjusting the pH of the ink. It is rare that the ink will ever need dilution as a form of viscosity control, but it is possible under certain conditions, such as long press runs in warm environments with low rates of ink consumption. If it is suspected that the solids content of the ink is increasing, a weight assay can be done with an oven and a precision balance, or a sample can be sent back to PChem in a tightly sealed container for analysis. The procedure for assessing solids content of the ink is described briefly below:

1. Mix material to be tested thoroughly to ensure uniform dispersion of silver throughout. Try to minimize time between mixing and aliquot removal for testing.
2. Weigh an aluminum sample cup on a 0.1 mg accuracy balance (or better) and record the value.
3. Apply about 0.5g of material (plastic pipette, etc) inside the well of the cup trying to spread the material uniformly, but not at the sacrifice of the material drying out too quickly. Re-weigh the sample plus aluminum sample cup on 0.1 mg balance.
4. Bake the sample at 80℃ for 5 minutes.
5. Bake the sample at 140℃ for 5 minutes.
6. Re-weight the sample cup with cured silver. Be careful not to spill any silver from the cup once it is cured as it may be flaky especially if the cup is flexed.
7. Calculate the wt % solids by subtracting the sample cup weight from the values for the wet and cured ink and dividing as per this equation:

$$\chi_{solids} = \left[\frac{\left(W_{cured} - W_{cup}\right)}{\left(W_{wet} - W_{cup}\right)} \right] \times 100$$

where:

W_{cup} = weight of empty sample cup
W_{wet} = weight of wet ink + sample cup
W_{cured} = weight of cured silver + sample cup

If it is determined that the solids content of the ink has increased to an unacceptable level, a diluent will be provided by PChem. Do not try to dilute the ink with water, alcohol, or any organic solvents.

Ink Management on Press

On press, PFI-722 loses both water and ammonia due to evaporation. Because of this, the viscosity and solids content will increase over time while the pH will decrease (as described previously in the pH adjustment section). The rate of evaporation is dependent on many factors including relative humidity, ink consumption rates, anilox volume, press speed and setup, and sump volume. As a general guideline on a commercial printing press, a 0.7% solids increase per hour is observed. Regular additions of 0.5wt% aqueous ammonia directly to the ink pan (setup permitting) accompanied by ink mixing is recommended to maintain ink quality of PFI-722.

For example, if 1 Kg of ink is on press with an estimated ink usage rate of 100 grams/hour, addition of 6.3 grams of 0.5wt% NH_3 solution (900g X 0.007) after 1 hour is recommended. Additional ink adjustment every subsequent hour of continuous printing is recommended. Ink adjustment solution can be added by pipette to the ink pan (not directly on the anilox) with continuous pan stirring using a wooden paint stirrer or a built-in pump system.

pH and solids measurements throughout the print run will be helpful in refining the specific maintenance procedure. PChem Associates will work closely with printers to establish and refine on-press ink management protocols.

Application Guidelines

Mix ink well before using. Measure pH and adjust if necessary. Unapproved thinners, such as water or organic solvents should **not** be added to the ink.

Anilox Roll Guidelines

Anilox volumes between 1 and 8 BCM have been used successfully. As with other flexo printing, low volume aniloxes should be used for fine features, and high volume should be used for thick lay-downs. To achieve resolutions below 25µm, volumes between 1 and 1.5BCM should be used. The resulting dry film thickness will be about 120nm * anilox volume (BCM).

Anilox Volume (BCM)	Approximate dry film thickness (µm)*
1	0.120 µm
2	0.240 µm
4	0.480 µm
8	0.960 µm

* These values represent typical thicknesses observed. Variations due to a number of factors including print speed, line width, and impression pressure may influence the dry film thickness of PFI-722.

Print Plates

For general printing, most commercially available plate formulations are suitable. For high resolution printing (<30µm features), we recommend Kodak Flexcel NX plates and soft mounting tape, such as 3M's 11-series tapes. For dense solids, tinted plates can improve mottle and density, and therefore sheet resistance. These effects are highly dependent on process conditions, so no specific recommendations are made. When fingerprinting the process using PFI-722, we suggest trying a range of 60% to 100% tint at various line-screens to find the condition yielding the best density/sheet resistance. As a default, 100% tint (solid) plates will still deliver excellent print quality. Tinted plates should not be used for fine features (<100µm).

Print Speed

As with many flexo inks, increased speed usually results in decreased mottle and improved print density. The press should be run at the maximum speed that still allows for sufficient curing. With multiple IR and convection oven banks, speeds over 600FPM have been achieved.

Curing Guidelines

PFI-722 can be cured with IR, convection, or conduction heating. The fastest results will be achieved with IR and conduction heating. Heating with 100 w/in short wavelength IR lamps will cure the ink fully in under 2 seconds. Back side conduction heating at 140℃ will cure the sample in under 15 seconds. Pure convection heating of suspended samples at 140℃ will cure the sample between 15 and 90s, depending on the rate of air impingement. Lower cure temperatures will result in longer cure times. Temperatures as low as 100℃ can be used with cure times under 1 minute. Please contact PChem for more details on cure kinetics and for advice on oven design for new installations.

Anilox Cleaning Procedures

WARNING: Proper prevention is essential for easier anilox clean-up. The anilox should never be allowed to dry-in. The anilox should be kept spinning in the ink until the very

moment it is ready to be cleaned with soapy water. If there is any lag between the anilox stopping and the cleaning procedure, then rags dampened with soapy water can be placed on the anilox to prevent drying-in until proper cleaning can be done.

Materials and Personal Protection Equipment

Eye protection and latex or nitrile gloves
General purpose dish soap (Palmolive, Dawn, etc.)
Iron (III) nitrate nonahydrate ($Fe(NO_3)_3 \cdot 9H_20$)
Harper CeramClean II™ or similar abrasive anilox cleaner

Cleaning Solution Preparation

Solution #1 - Soapy water: approximately 1:10 by volume mix of general purpose dish soap (Palmolive, Dawn, etc.) to water. Dilute 1 part dish soap with 10 parts water and mix until homogenous. Use de-ionized or distilled water if available.

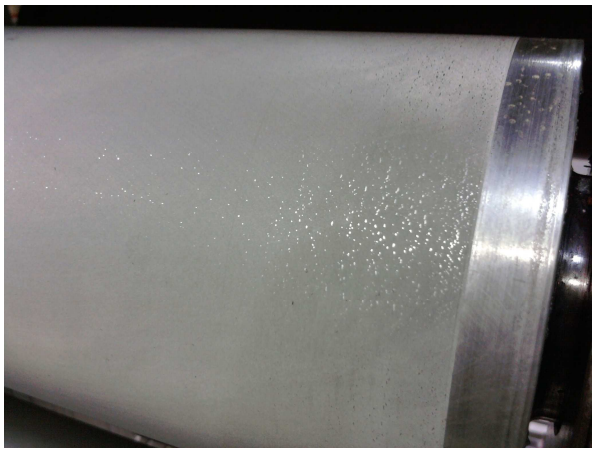
Solution #2 - Ferric Nitrate Solution: 50:50 by weight mix of Iron (III) nitrate nonahydrate ($Fe(NO_3)_3 \cdot 9H_20$) to water. Agitate until all crystals are in solution. Solution should have a light brown appearance. Use de-ionized or distilled water if available.

WARNING: Do NOT use solvents (ethyl acetate, alcohol, etc…) or alkaline pH aqueous ink cleaners on the anilox roll still coated in PChem silver ink.

Step 1: Drain the bulk of the ink from anilox chamber or pan to prevent the soap solution from mixing with the ink. If an open pan anilox is being used, back off on the doctor blade leaving the anilox soaked with ink while draining ink. If the anilox is assembled in a chambered doctor blade on the printing press, pump the bulk of the ink out, then immediately circulate soap solution through the chamber

while wiping with rags or wire brushing the anilox while it is still installed on the press. Wipe down the anilox roll with rags saturated in soapy water solution. Repeat until the rags appear clean. Reclaim all inked rags for silver recycling.

If the anilox roll appears significantly free of silver after cleaning with soapy water than it can be used without proceeding to the following steps. However, if there appears to be silver residue or the cells are entirely clogged with silver as pictured below then the following steps can be used to remove all remaining silver residue.



Step 2: Wipe down the anilox with a dry rag to remove residual soap. Submerse the outer surface of the anilox roll in a shallow pan with ferric nitrate solution. Rotate to evenly coat anilox surface continuously for 10-15 minutes. Alternatively the ferric nitrate solution can applied using a pipette or sponge while being scrubbed with a rag, sponge, or a wire brush. **Ferric nitrate is corrosive, and should not come into contact with the skin or eyes.**

Step 3: Wipe down excess ferric nitrate solution with a rag and dispose of rags and ferric nitrate solution properly.

Step 4: Apply a liberal amount of CeramClean II™ directly on the anilox roll surface.

Using a clean damp rag/towel spread the Ceramclean II over the roll surface in a circular motion and agitate with a wire brush appropriate to the type of anilox roll. Rinse surface with clean water to make certain all the cleaner is removed from the surface of the roll.

Repeat steps 2 through 4 as necessary.

Plate Cleaning Procedures

Flexographic plates used in the printing of PFI-722 can be cleaned with isopropyl alcohol (IPA) and absorbent fiber-free wipes (Foamtec UltraSORB Foam Wipers, polyester clean room wipes, or similar product). Continue cleaning with IPA/Wipes until no residue is removed by a clean wipe. Make sure all solvent has evaporated before attempting to ink the plate again.

Material Recycling

PChem Associates recycles all ink and printed product waste streams containing silver, and we encourage our customers and partners to do the same. Up to 80% of the current market value of the reclaimed silver can be returned to the user through recycling. Please contact PChem Associates for more information.

Health and Safety

Good health and hygiene practices should be followed. Safety glasses, chemical resistant gloves, and a lab coat should be worn at all times. Proper ventilation should be used at all times when working with this material. Upon heating/curing, the oven should be exhausted outside the building. See the PChem MSDS for more information.