SENKO®
Advanced Components

Application Note

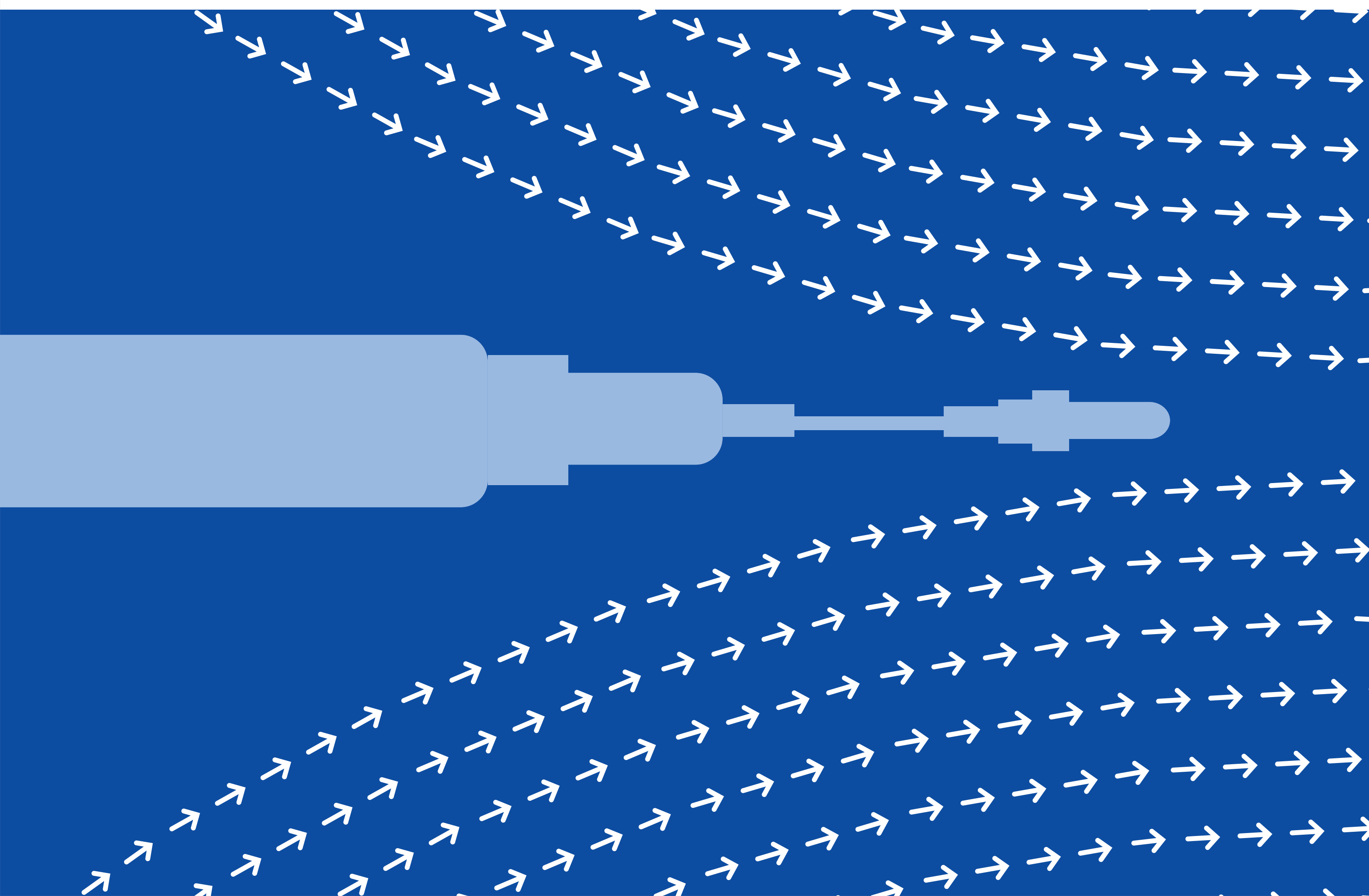
senko.com

Epoxy Injection into Fiber Optic Connectors

MARCH 2022
Rev. 01

Issued by:
Engineering Department

Created by:
Andrei Vankov



1.0 Introduction

Securing fiber optic connectors with epoxy is a critical step of the connector termination process. Any mistake with storing, mixing, dispensing, or curing of the epoxy, could adversely affect a connector's performance in the field due to premature bond failures. This application note provides information on this critical process based on SENKO's experiences gained through years of manufacturing and reliability testing.

This document is centered around injecting epoxy into connectors featuring composite or ceramic ferrules. For multifiber connectors such as MPO please refer to the Application Note called MT Ferrule Epoxy Injection Techniques.

It is important to note that working with epoxies requires personnel protection. It is recommended to work in a well-ventilated area or under an exhaust hood wearing latex or nitrile gloves to reduce any dermal exposure. In the case of epoxy spillage, acetone or IPA (Isopropyl Alcohol) can be used to carefully clean it up.

2.0 Epoxy properties

The fiber optic termination process starts with selecting a proper epoxy type that is suitable for the desired application. There are many varieties of epoxy that are available currently in the market. The adhesives may have slightly different physical properties and curing schedules. Prior to using the epoxy, it will need to be mixed with a proper ratio measured by weight. Part A is typically a hardener and part B is a resin. Thus, a fiber optic epoxy is a two-part structural adhesive that bonds the fiber glass silica to the zirconia ceramic ferrule. It has low outgassing levels, a high glass transition temperature (T_g) and shrinks minimally upon curing.

It is important to understand exactly what T_g is and how it could influence connector performance in various temperature and humidity environments. T_g should not be confused with melting point temperature (T_m). T_g is the temperature range in which a thermosetting polymer changes from one molecular phase such as a hard "glass" state to another molecular phase that is a more pliable "rubbery" state. When this phase change occurs, typically in a high temperature operation environment, the fiber could break the epoxy bond and retract or piston back creating an undesirable air gap in the interconnect. In actuality T_g is not a discrete thermodynamic transition, but a temperature range over which the mobility of the polymer chains increase significantly. The ultimate T_g is determined by several factors: the chemical structure of the epoxy resin, the type of hardener that is used by the manufacturer, and the curing schedule. Low temperature cures will result in the lower T_g. As an example, a SENKO adhesive S-123 could have a T_g between 80°C and 120°C, depending on the cure temperature and time. Therefore, it is important to cure at a maximum allowable temperature while maintaining precise temperature control in a production setting. That is why a Technical Data Sheet (TDS) has recommended the cure schedule as a function relating temperature and time: the higher the temperature, the faster the epoxy will cure.

SENKO Advanced Components

Cure Schedule:

Temperature	100°C	**OR**	120°C	**OR**	150°C
Time	5 minutes		2 minutes		1 minute

****For maximum physical properties a post---cure for 15 minutes at 120°C is recommended***

SENKO has a proven track record with connectors passing strict GR-326 environmental requirements that feature uncontrolled environment where temperatures vary from -40 to 85C. To achieve these results SENKO has developed custom curing schedules for many connectors using SENKO S-123 adhesive. Contact a SENKO sales representative for more information.

Once an appropriate adhesive is selected, it is important to note the shelf life and recommended storage temperatures. For example, a common Epotec 353 ND or S-123 epoxy has a shelf life of 365 days when stored at 23°C. This time frame begins on the date the epoxy was packaged at the manufacturer. On occasion during storage at room temperatures epoxy may look foggy or grainy. Most likely if the storage temperature was stable, a crystallization process could occur, because the liquid resin may start a natural solidification. In this case, the epoxy is still usable. To validate this point, the pack can be gently heated to about 65 °C for a period of 15 minutes and it should return to a clear liquid state.

Epoxies also have a limited working life. Typically, after mixing the workable viscosity is maintained for a certain amount of time depending on the epoxy type and the ambient temperature in the manufacturing facility. As the epoxy thickens, the pressure that is applied to a plunger dispenser needs to be increased in order to keep up with consistent volume dispatch. The epoxy technical data sheets will have values for Pot Life and Working Life. These two should not be confused as it is not the same thing. Pot Life is defined as the amount of time it takes for an initial mixed viscosity to double (or quadruple for lower viscosity products). Working Life, on the other hand, is the amount of time an epoxy remains low enough in viscosity that it can still easily be dispensed from a syringe. For these reasons, Working Life can vary due to ambient air properties of the facility, the application, and even the connector type.

3.0 Epoxy types used in the Fiber Optic industry

Most fiber optic epoxies are two-part systems, which are formed through the polymerization of two starting compounds: a resin and a curing agent. The curing process takes place when the reactive materials of the resin and curing agent combine. During initiation of the reaction, an exothermic process develops, enhancing the crosslinking of the two components. Two-part versions are stronger than one-part alternatives because of this bonding type mechanism. That’s why it is necessary to thoroughly combine and mix the two-part adhesives to ensure the best performance.

Proper epoxy mixing, application and curing is necessary for a successful final result. Senko's recommended epoxy is S-123 which consists of Parts A and B. These parts need to be thoroughly mixed. The typical mixing ratio is 1 part of hardener to 10 parts of resin measured by mass. Proper mixing allows for the best possible performance of an adhesive. It is required to use a scale that has a resolution of one hundredth of a gram. A 3cc syringe typically filled with approximately 2.5 grams of epoxy which would mean as an example 0.27 grams of resin and 0.23 grams of hardener ration-vise when measured by weight, meaning you will need 5 times 0.27 grams of resin mixed with 5 times 0.23 grams of hardener. It is challenging to measure properly. A minimum of two grams of material should be used each time a product is mixed. This will ensure there is enough material for the hardener to adequately distribute in the resin.

Often epoxy can be ordered in so called bi-pax. This is slightly more expensive compared to buying in bulk, but it prevents dealing with weighing the parts on a precision scale. Pre-weighted epoxy components Part A and Part B are separated with the clip or burst seal and come in one pouch. It is recommended to use a roller for mixing the epoxy for approximately 45 seconds to ensure both epoxy components are homogenously distributed and the package turns into one uniform color.

Figure 1 Roller used to mix epoxy in bi-pax

After mixing the epoxy, air bubbles will inevitably be present. To draw the bubbles out of a freshly mixed liquid epoxy, commonly a centrifuge with a constant 3600-rpm speed and 6-inch chambers is used in the industry. The centripetal acceleration of the centrifuge forces the heavier adhesive to settle to the bottom while the lighter air bubbles rise to the surface and are released. Bubbles and voids in fiber optic assemblies may result in serious performance and reliability problems. This is mostly due to irregular stress conditions however, assembly failure could occur over time when a bubble or a void creates a condition that allows lateral loading forces to a fiber. This can cause micro-crack propagation and breakage. Typically, a 7–10-minute spin cycle in a centrifuge will draw the air bubbles out. Failing to degas the epoxy could also reduce the proper fiber to ferrule bond because air expands at high curing temperatures. This reduces epoxy bonding strength, which causes the fiber to move during environmental temperature changes.

Figure 2 Epoxy after mixing contains undesirable bubbles

Figure 3 Epoxy after being centrifuged is bubble free

Finally, it is possible to purchase a frozen epoxy pre-packaged in syringes that are premixed and degassed. This would be the most expensive option starting with the fact it will be shipped in dry ice to keep it frozen at -40°C. Once the package is received, the syringes should be moved into a freezer at -40°C as soon as possible. Prior to using it, a thaw time will be required with the needle end pointing down. Refreezing epoxies is conceivable, but typically is not recommended due to the possibility of tracking moisture from exterior environment.

4.0 Applying epoxy techniques: manual versus automated dispensing

Once the selected epoxy is properly mixed, degassed and transferred to a syringe it is ready to be used. Dispensing can be manual or automatic. We will consider manual first. Manual is a less expensive option as it requires just a 3cc syringe with a 20-22 Gage needle.

SENKO recommends the following technique in the Engineering Termination Procedures (ETP) for ceramic ferrules:

1. Wipe clean the needle tip before applying the epoxy. Push epoxy application needle up into the back of the flange so that it bottoms out against the back of the ferrule.
2. Carefully Inject the epoxy into the ferrule and clean the ferrule assembly with alcohol including excess epoxy from the metal flange.
   Recommended manual technique: Hold the body with the ferrule pointing up. Press the syringe plunger gently until a very small bead of epoxy appears on the tip of the ferrule. Slowly retract the syringe.
3. Clean the bare optical fiber with lint free wipe soaked with IPA (99% Isopropyl Alcohol), and then insert the optical fiber into the back of the connector body. The fiber is fully inserted when the buffer tube bottoms out on the back of the ferrule.

Note: Be careful not to break the fiber, insert the fiber slowly.
Note: Be careful not to damage bare fiber protruding from the connector ferrule.

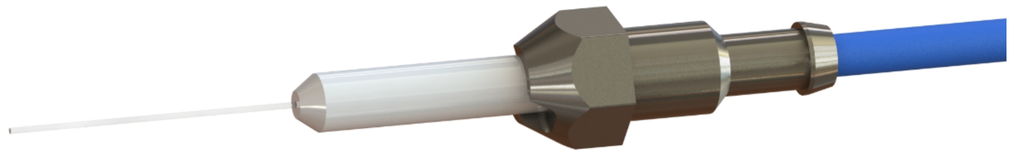


Figure 4: Insert fiber into ferrule

SENKO instructions have additional professional tips that explain the proper epoxy amounts required inside of the ferrule from a different perspective. For example:

Ensure sliding the fiber buffer or loose tube all the way to the ferrule ceramic "well" filled with epoxy. The back-end of the ferrule (where it is pressed into the ferrule-holder) should have sufficient epoxy fill to ensure the fiber strip point can be fully encapsulated with epoxy.

Too little epoxy could lead to bubbles and voids and may cause the fiber to not be fully encapsulated, drastically increasing risk of fiber breakage.

Too much epoxy may spill-over the ferrule holder after inserting the fiber, which may lock-up or interfere with connector spring-action.

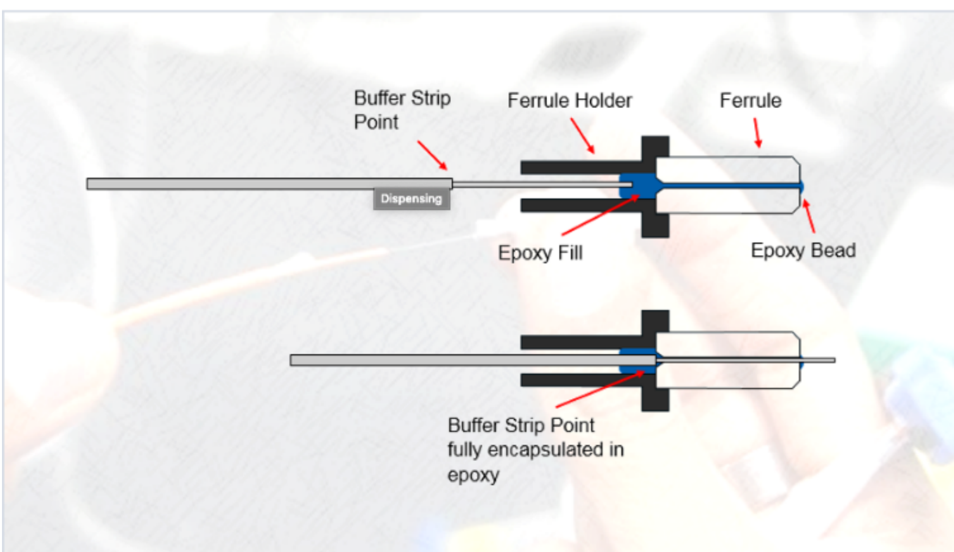


Figure 5 Proper ceramic "well" fill

The “Epoxy Injection” process requires robust process controls, as it is nearly impossible to verify the effectiveness of the proper ferrule fill immediately at the termination station.

To verify the adequate epoxy amounts SENKO suggests performing periodic ferrule cross section inspections. These can reveal how much epoxy is inside, whether the epoxy encapsulates the fiber correctly inside the “well”, and if there are any bubbles present. Not enough epoxy, or large voids in the “well”, may cause the fiber to not be fully encapsulated. This drastically increases the risk of fiber breakage. Too much epoxy in the ferrule and it may spill out the back the ferrule holder after inserting the fiber, this may undesirably lock-up the connector spring or fiber.

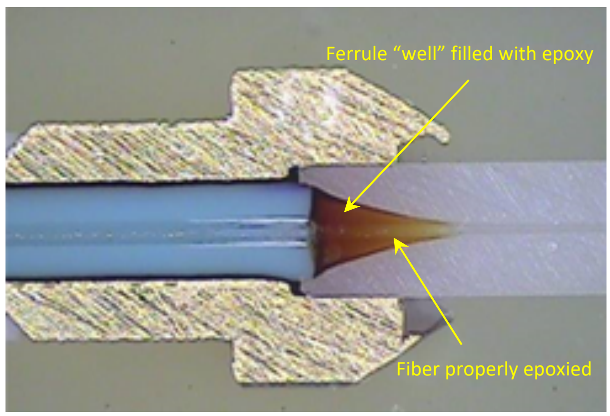


Figure 6 Proper "well" fill has no epoxy voids

However, the better way to ensure the epoxy dispensing process has a repeatability and control is to use automated epoxy dispensing. Automated epoxy dispensing brings consistency to epoxy amounts inside the connectors. The automated epoxy station is a precision dispensing system that applies accurate, consistent amounts of epoxies used in benchtop assembly processes. Benefits of the systems’ consistent fluid application include: higher yields, better process control and shorter training time for new operators. There are many Automatic Dispensing Systems (ADS) available in the market. Some of them use pneumatic air pressure to press the syringe plunger, some of them have a lead screw for applying pressure. In general, epoxy viscosity remains consistent for the first 30-40 minutes after mixing. The viscosity increases in time requiring changes of pressure on the plunger in order to keep up with correct epoxy volumes. Note, the epoxy will remain within a work life limits, however the viscosity will be different. In this case the ADS that has a metered mechanical feature for applying pressure on the plunger. This would show more consistency in epoxy dispensing amounts during viscosity changes. For example, the method that uses an electronically controlled lead screw to push the syringe’s piston can keep track of the amount dispensed with each shot and alert the operator when it is time to load a new syringe. This approach achieves in theory the most accurate and repeatable dispensed epoxy quantity, and it requires the least amount of operator training. This method is well-suited for any operation, but it can be more expensive than other methods.

It would be a manufacturing engineers' area of expertise to develop the optimum ADS techniques, including identifying the syringe needles shape and size, fixturing, etc. For example, a 22-gage needle might work better for 1.25mm ferrules, while for SMA connector types, a 20-gage would be more suitable. Before dispensing epoxy the needle needs to be inserted all the way into the metal ferrule flange against the ceramic ferrule "well". It is better to have a syringe secured in the fixture with the needle pointing up and to use a foot pedal for pressure activation. That way a technician will have both hands free for maximum control to inspect and clean the needle before changing the connectors. Connectors or ferrules can be pointed up for easier visual epoxy bead assurance as shown in Figure 7. Holding the connector firm with the fingers and pressing the pedal while holding it makes it possible to prepare connectors in volumes for the production line. After epoxy injection an operator should see a uniform bead at approximately 0.2mm in diameter. It is advisable to store epoxy injected ferrules in trays with end-faces down as in Figure 8. This way epoxy will not leak out and it will settle in the ferrule well properly.

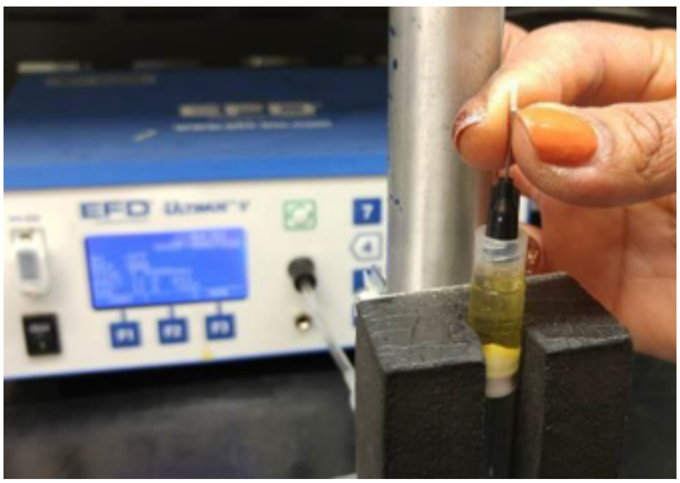


Figure 7 Example of syringe holder for ADS

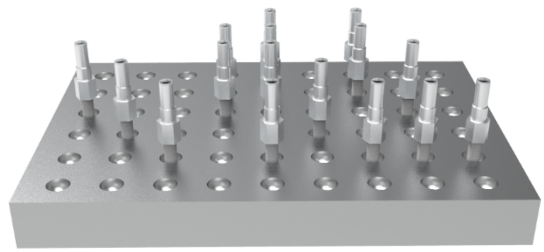


Figure 8 SENKO recommends using vertical trays where the ferrules with dispensed epoxy can be stored with flanges up.

Using ADS helps in consistency of epoxy bead sizes. After cleaving, the fibers remain encapsulated in a greatly reduced, consistent, and supportive epoxy bead. This means that they are sufficiently protected for the initial polishing stage. This results in increased process speed and higher output. Automation should be considered whenever production volumes justify upfront investments through Return on Investment (ROI) calculations. Many military and defense customers require automation in epoxy dispensing processes as this assures quality and reliability.

5.0 Conclusion

Epoxying is an important part of the termination production process, which should result in quality, yields, and efficiency. SENKO can help the manufacturers select proper epoxy for an application, the dispensing method and level of automation to meet their needs, depending on their daily volumes, connector types, and workflow.

There are two epoxy dispencing approaches most commonly used - manual and automated:

1. Manual approach relies on the skill of an operator to gage the epoxy amount after pressing the syringe's plunger, inspecting the end-face epoxy bead, and determining if the ferrule is correctly filled. Manual dispensing is inexpensive and practical for small manufacturers with low production volumes.

2. Automated approach allows an operator to connect the epoxy filled syringe to a machine that uses set air pressure to press the plunger and dispense a controlled amount of adhesive. More sofisticated ADS have additional controls that regulate the applied pressure to compensate for the reduced amount of adhesive due to viscosity changes in time. With automatic dispensing, the process is less dependent on operator's skills, but there is additional capital expense for the equipment. The advantage is better control over the quantity of adhesive being dispensed with each shot versus a manual injection.

SENKO®
Advanced Components

Contact us

USA
East Coast +1-508-481-9999
West Coast +1-858-623-3300
Texas +1-972-661-9080
Sales-Americas@senko.com

Mexico & Central America +1-858-623-3300
Sales-Mexico@senko.com

Brazil and South America +55-21-3736-7065
Sales-Brazil@senko.com

Asia-Pacific
Hong Kong +852-2121-0516
Shanghai +86-21-5830-4513
Shenzhen +86-755-2533-4893
Thailand +66(0)2-163-2798
Australia +61(0)3 9755-7922
Sales-Asia-Pacific@senko.com

Japan
Yokkaichi City +81-59-352-1121
Tokyo +81-3-5825-0911
Sales-Japan@senko.com

United Kingdom
UK +44(0) 1256 700880
Sales-UK@senko.com

Europe
Spain & Portugal
Sales-Iberia@senko.com

Germany
Sales-Germany@senko.com

Italy
Sales-Italy@senko.com

France
Salesfrance@senko.com

Other European Countries
+44(0) 1256 700880
Sales-Europe@senko.com