

CLEANING TIP FOR NON-CONTACT CLEANING OF FIBER OPTIC CONNECTORS
AND END FACES

CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit of US Application No. 63/587,342, filed on October 2, 2023 and entitled "Cleaning Tip for Non-Contact Cleaning of Fiber Optic Connectors and End Faces", the disclosure of which is incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention generally relates to a cleaning tip for use in non-contact cleaning of fiber optic connectors and the end faces of optical fibers. The ferrule end surfaces may be efficiently cleaned whether they are exposed or installed in a ferrule connector such as a plug or a bulkhead for interconnection with another optical fiber or with an optoelectronic device.

[0002] In fiber optic networks, optical fiber strands, which typically have a diameter of about 8 micrometers, are connected by encasing the strands in protective jackets (not shown) to form cables and butting two cable ends together. To do this, the ends of the individual fiber optic strands 10a, 10b, 10c (Figures 1A, 1B, 1C) are typically stripped of the jacket and are bonded and encased in the center of a rod-like ceramic ferrule 12a, 12b, 12c. This ferrule provides an enlarged surface area for finish polishing of the exposed end face of the optical fiber strand. The ferrule end faces 14a, 14b, 14c are polished either flat (Figure 1A), slightly convex (Figure 1B), or angled at approximately 8 degrees (Figure 1C) to reduce reflected light when connected to another optical fiber. These ferrules are then fitted into various types of connector housings, e.g., connector 16 (Figure 2), which precisely interconnect with similar devices, e.g., connector 16' (Figure 3), via a coupler or bulkhead 18 to insure the exact alignment of the butted optical fiber strands. For cleaning, the assembly of Figure 3 is disassembled to expose the ferrule end face for cleaning while it is still connected to its associated half of coupler or bulkhead 18.

[0003] Figure 4 shows the end of a fiber optic cable 19 comprising a fiber optic strand 20 having an outer protective jacket or sheath 22, the end portion of which is stripped away with the stripped portion of strand 20 encased in a ferrule 24 having an end face 24a. Ferrule 24 has affixed to its end face 24a a lens 26 which may be of spherical or approximately spherical configuration to render ferrule 24 an expanded beam ("EB") ferrule. Lens 26 is

usually a collimating lens although it may be an imaging lens. In any case, lens 26 is disposed in optical-transmitting relation to the end of its associated fiber optic strand 20.

[0004] Figure 5 shows a pair of optic fiber cables 19, 19', each having respective EB ferrules 24, 24', whose respective lenses 26, 26' are optically connected to each other by connectors 28, 28'. Connectors 28, 28' may be connected to each other by any suitable means, such as mechanical fasteners or couplers. Connectors 28 and 28' are each configured to be uncoupled from each other in order to permit inspection and cleaning of the disconnected ferrule end faces 24, 24' and their associated lenses 26, 26'.

[0005] Figure 6 shows one of the connectors, connector 28, of Figure 5, disconnected from its associated connector 28' and thus ready for cleaning.

[0006] Cleanliness of cable connections such as those described above is a critical factor in maintaining peak signal communication performance, but such cable connections are highly susceptible to contamination at the abutting end faces of the optical fibers. Therefore, it is essential that the end surfaces be cleaned before the optical fiber ends are connected to each other, and/or after they become contaminated during normal use.

2. Prior Art

[0007] U.S. Patent 7,232,262 issued June 19, 2007 to S. Lytle et al. ("Lytle") discloses a cleaning apparatus for cleaning an end face of an optical fiber contained in an interface device utilizing a pressurized fluid such as air or nitrogen to deliver a solvent by inserting the device into the optical fiber connector 200.

[0008] U.S. Patent 6,821,025 issued November 23, 2004 to G.J. Gerhard ("Gerhard") discloses in Figure 2 a device including a pressurized gas/cleaning solvent discharge port or nozzle 114 spaced from the fiber optic end face 202 in a manner similar to that described in Lytle.

[0009] The Lytle and Gerhard patents disclose cleaning of fiber optic end faces without physical contact with the fiber optic end face, but require insertion of a nozzle into the connector or other structure associated with the fiber optic connector. Other patents disclose contact cleaning in which a swab or cloth is physically contacted with the end face. For example, U.S. Patents 7,401,374 issued on July 22, 2008 to J.S. Tourigny and 9,798,093 issued on October 24, 2017 to J.S. Tourigny, both assigned to the assignee of this application, disclose manually operated swab-like cleaning devices for cleaning optical fiber end faces disposed within connector couplers or bulkhead receptacles.

[0010] US2002/162582 A1 published November 7, 2002, naming Chu et al. ("Chu") as inventors shows in Figure 5 and the description at paragraphs [0047] - [0049] an ultrasound cleaning device which includes a vibration transference structure 420 having a threaded interface 418 to which a probe tip 440 is threaded to provide a probe tip assembly 404. In paragraph [0047] the probe tip assembly is described as being exchangeable. A liquid-filled gap 450 is formed between the probe tip nozzle 442 and the ferrule 14.

[0011] US 9,891,389 issued February 13, 2018 to Fredell et al. ("Fredell") discloses, starting at column 6, line 2, a nozzle assembly 180 (Figure 5 and enlarged cross sectional views in Figures 6A and 6B) in which nozzle 100 includes an inner housing member 130 disposed within an outer housing member 110. As best seen in Figure 6B the front-end section 142 of inner housing member 130 extends into the tubular gap 70 of connector housing 30. Front-end section 142 is spaced from interior surface 48 of interior wall 46.

[0012] US 11,668,882 issued January 6, 2023 to Brown et al. ("Brown") discloses, starting at column 3, line 47, a cleaning system 10 (Figure 1A) including a nozzle assembly 20 and a cleaning fluid delivery device 30 which delivers a cleaning fluid 32 to clean a ferrule front end 62. Figure 1B and Figure 2 show ferrule 60, which is part of an optical fiber connector 56, connected to fluid delivery device 30. Adapter 40 provides an interior space 46 in which the cleaning fluid 32 impinges ferrule end face 74 to clean the fiber end face 94.

[0013] A contact-free method of cleaning fiber optic connectors and end faces is disclosed in International Patent Publication Number WO 2022/216640 A1 published on 13 October 2022 and in its national stage U.S. Patent Application Serial No. 18/552,601, filed on September 26, 2023 and entitled "Method for Non-Contact Cleaning of Fiber Optic Connectors and End Faces" ("the '601 Application"). The entire subject matter of the '601 Application, which is assigned to the assignee of the present application, is incorporated by reference herein.

SUMMARY OF THE INVENTION

[0014] The present invention provides a cleaning tip which is well suited for use with a device, such as that shown in the '601 Application, which delivers a pressurized gas flow to clean fiber optic connectors and end faces, in particular, with such devices adapted to employ non-contact cleaning as described in the aforesaid '601 Application. Such devices are particularly useful for non-contact cleaning of fiber optic ferrule end faces used to mate optical fibers where a connect/disconnect capability is required. An atomized solvent is dispersed in the gas flow during a cleaning period and the solvent is discontinued to provide a dry (no

solvent) gas flow during a drying period. The gas flow is sometimes herein referred to as the "cleaning fluid" whether or not the gas flow includes atomized solvent.

[0015] Specifically, in accordance with one aspect of the present invention a cleaning tip for the nozzle of a cleaning device, the nozzle having a nozzle outlet from which a cleaning fluid is emitted for cleaning a fiber optic end face juxtaposed to the nozzle outlet, such fiber optic end face being disposed in a housing member having a housing member contact face, and the cleaning tip is dimensioned and configured to have such cleaning fluid flowed therethrough. The cleaning tip comprises: a spacer tube having a tube wall having an open terminal end and an opposite base end, and a mounting base disposed at the base end, the mounting base being dimensioned and configured to mount the cleaning tip on such nozzle in fluid flow communication with such nozzle outlet, whereby such cleaning fluid discharged from such nozzle outlet is flowed through the cleaning tip to impinge on such fiber optic end face. The tube wall has one or more vent openings therein to provide an exhaust outlet from the cleaning tip for such cleaning fluid; and the spacer tube is dimensioned and configured to provide a preselected stand-off distance between such nozzle outlet and such fiber optic end face when the terminal end of the spacer tube is placed in contact with such housing member contact face.

[0016] Other aspects of the present invention may provide one or more of the following features in any suitable combination: the cleaning tip may comprise a plurality of vent openings disposed circumferentially about the spacer tube; the spacer tube has an outer surface area and the total area of the one or more vent openings may comprise from about 30% to about 70% of the outer surface area; the cleaning tip may be dimensioned and configured to be removably mounted on such nozzle; and the mounting base may be threaded and threadably mounted on the nozzle.

[0017] Another aspect of the present invention provides for an assembly of (a) a cleaning device nozzle having a mounting pedestal thereon, and a nozzle outlet through which a cleaning fluid is impinged on a fiber optic end face juxtaposed to the nozzle outlet, the fiber optic end face being disposed in a housing member having a contact face, and (b) a cleaning tip mounted on the nozzle. The nozzle outlet may comprise a mounting pedestal and a needle plug movably disposed in the nozzle outlet to regulate flow of such cleaning fluid through the nozzle outlet, the needle plug diminishing in cross section in the direction of outward flow from the nozzle and terminating in a point. The cleaning tip is dimensioned and configured to have such cleaning fluid flowed therethrough, the cleaning tip comprising a spacer tube having a tube wall having a terminal end and an opposite base end, and a

mounting base at the base end, the mounting base being mounted on the mounting pedestal with the needle plug disposed within the cleaner tip and the cleaner tip disposed in fluid flow communication with the nozzle outlet; and the tube wall has one or more vent openings therein to provide a tube wall outlet and define a flow path for such cleaning fluid from the nozzle outlet through the cleaner tip and out the vent opening.

[0018] Other aspects of the present invention provide one or more of the following features in any suitable combination: a plurality of vent openings may be disposed circumferentially about the spacer tube; the spacer tube has an outer surface area and the one or more vent openings have a total area which is equal to about 30% to about 70% of the outer surface area of the spacer tube; the mounting base may be removably mounted on the mounting pedestal; the mounting base and the mounting pedestal may have respectively complementary threads and the mounting base is threadably mounted on the mounting pedestal; the nozzle may further comprises a needle plug housing within which the needle plug is disposed, the needle plug housing having an inside diameter which is greater than the outside diameter of at least that portion of the needle plug disposed within the needle plug housing whereby to provide an annular channel for flow of the cleaning fluid over the needle plug; and the needle plug housing may be a snug slidable fit within the spacer tube and is disposed within the spacer tube so as to occlude at most a portion (some, not all) of the vent openings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Figure 1A is a cross-sectional view of a ferrule end with the end of an optical fiber therein, with a flat end surface according to the prior art;

[0020] Figure 1B is a cross-sectional view of a ferrule end with the end of an optical fiber therein, with a convex end surface according to the prior art;

[0021] Figure 1C is a cross-sectional view of a ferrule end with the end of an optical fiber therein, with an angled end surface according to the prior art;

[0022] Figure 2 is an elevation view of a connector fitting with a ferrule end therein according to the prior art;

[0023] Figure 3 is a partly cross-sectional view of two ferrule ends with optical fibers therein in a coupling to interconnect the optical fibers according to the prior art;

[0024] Figure 4 is a schematic cross-sectional view of a ferrule end with the end of an optical fiber therein, with an expanded beam end surface according to the prior art;

[0025] Figure 5 is a schematic cross-sectional view of two ferrule ends with expanded beam optical fibers therein in a coupling to interconnect the optical fibers according to the prior art;

[0026] Figure 6 is a schematic cross-sectional rendition of one of the ferrule connectors of Figure 5;

[0027] Figure 7A is a schematic illustration of ambient air pressure acting on a jet of air or other gas;

[0028] Figure 7B is a schematic illustration of the air jet of Figure 7A traversing the surface of a curved or bent structure;

[0029] Figure 7C is a schematic cross-sectional view of the nozzle end of a prior art cleaning device and a fiber optic end face being cleaned by the cleaning device;

[0030] Figure 8 is a schematic view in elevation with part broken away, of an embodiment of the cleaning tip of the present invention showing how it is to be mounted on the nozzle of a cleaning device;

[0031] Figures 9A-9C are schematic cross-sectional plan views of the spacer tubes of different cleaning tip embodiments of the present invention;

[0032] Figure 10 is a schematic view in elevation with part broken away of a cleaning tip embodiment of the present invention mounted on a cleaning device nozzle to provide a stand-off distance of the nozzle to a male fiber optic connector; and

[0033] Figure 11 is a schematic view in elevation with part broken away of a cleaning tip embodiment of the present invention mounted on a cleaning device nozzle to provide a stand-off distance of the nozzle to a female fiber optic connector.

DETAILED DESCRIPTION OF THE INVENTION

[0034] The cleaning tip of the present invention is advantageously used in connection with a cleaning device which is usable to carry out the non-contact cleaning method of the aforesaid '601 Application. Such cleaning devices comprise a dispensing nozzle adapted to deliver a narrow jet or column of pressurized gas and for a part of the cleaning cycle atomizes a solvent within the narrow column of pressurized gas, e.g., air, carbon dioxide, nitrogen or other suitable gas. The gas flow provided by the pressurized gas jet or column carries an atomized solvent for a solvent cleaning period of the cleaning cycle, and the solvent is discontinued for a second, drying period of the cleaning cycle. The dispensing nozzle is positioned to selectively direct both the narrow column of pressurized gas, and the narrow column of pressurized gas and atomized solvent, onto the entire surface of a fiber optic end face

regardless of end face surface geometry including extreme end face geometries, e.g., an expanded beam lens, to remove contaminants on the end face, whether or not the end face is contained within an adapter. A method for cleaning an end face of an optical fiber, comprises the steps of establishing and directing a narrow column of pressurized gas flow dispensed from the nozzle and flowed over a needle plug which is dimensioned and configured to create the Coandă effect in the gas flow, as described below and toward and into contact with the end face. A solvent is injected into the pressurized gas to atomize the solvent into droplets that mix with the pressurized gas in the gas flow to provide non-contact cleaning of fiber end faces, and then discontinuing the solvent to deliver a column of pressurized gas, e.g., air, to dry the end face after the solvent flow is discontinued.

[0035] Any suitable solvent composition may be employed in the practice of the present invention. As disclosed in the '601 Application, the distance of the tip of the needle plug, and therefore of the nozzle outlet, from the end face of the fiber optic being cleaned must be carefully controlled to attain the desired cleaning result.

[0036] As disclosed in the '601 Application, the cleaning device may comprise a nozzle having a nozzle outlet, within which nozzle outlet is disposed a needle plug of diminishing cross section in the direction of outward flow through the nozzle outlet. The needle plug terminates in a pointed tip facing outwardly of the nozzle and is movable laterally to act as a valve to control gas flow through the nozzle outlet. The nozzle outlet is aligned with such end face and the pointed tip of the needle plug is positioned at a stand-off distance of from about 0.25 inch to about 0.75 inch (0.64 to 1.91 cm) from such end face. This distance is sometimes herein referred to as the "stand-off distance". Specifically, in accordance with one aspect of the present invention there is provided a fixture comprising a cleaning tip to position the nozzle outlet of a device such as that of the '601 Application at the proper stand-off distance from the end face of an optical fiber to be cleaned by the device.

[0037] Figure 7C shows the nozzle end of a cleaning device in accordance with one embodiment of the aforesaid '601 Application, the usual controls employed to control the flow of gas and solvent and to operate the needle valve are omitted to simplify the drawings. Such controls are well known in the art and in and of themselves form no part of the present invention.

[0038] A cleaning device 100 comprises a housing 102 having a dispensing nozzle 104 at one end thereof. Dispensing nozzle 104 has two orifices, one orifice 106a at the discharge end of a gas passageway 106 and the other orifice 108a at the discharge end of a solvent passageway 108. Solvent orifice 108a is centered in the nozzle 104 and is closable by

means of a centrally positioned, movable, symmetrical shaped needle plug 110 that has a smooth sidewall which is slanted to end in a sharp point at the tip of the needle plug. The needle plug 110 is normally positioned so the solvent orifice 108a is in the closed position (not illustrated). A second outer, gas orifice 106a is in proximity to and concentric with the solvent orifice 108a. Orifices 106a and 108a are each circular in cross section.

[0039] Needle plug 110 is disposed at the exit of solvent passage 108 and is movable (leftwardly as viewed in Figure 7C) to close solvent passage 108 and (rightwardly as viewed in Figure 7C) to open solvent passage 108. This movement of needle plug 110 is indicated by the two-headed arrow V and it is seen that the amount of solvent flow is regulated by the position of needle plug 110 and any selected degree of opening between fully open and fully closed.

[0040] A stream of dry, filtered, compressed air from a source 112 of compressed air is flowed through line 114, and is passed through the air outer orifice 106a and parallel to the slanting sidewalls of needle plug 110. When solvent is to be introduced into the air stream from a source 116 of solvent, the solvent flows from source 116 through line 119 into solvent passageway 108. The moving compressed air, whether dry or containing atomized solvent, clings to the slanted shape of the sharp point of needle plug 110 which projects beyond solvent orifice 108a, which provides the Coandă effect, resulting in an area of low pressure that originates at the sharp point of the needle plug 110 and is indicated in Figure 7C by the unnumbered dash lines bordering jet column 118. The low pressure zone surrounds the jet column 118 and is somewhat trumpet shaped. The low pressure causes a concentration of airstream velocity and manipulates the airstream shape into a narrow jet column 118 that remains highly concentrated at a distance d the distance between the sharp point of needle plug 110 and the optic fiber end face 120. As disclosed in the aforesaid '610 Application, effective cleaning and drying requires that the distance d be accurately controlled. As taught in the '601 Application, distance d should be between 0.25 inch and 0.75 inch, that is, between 0.635 centimeters ("cm") and 1.905 cm. Maintaining distance d allows the concentrated jet column 118 to be focused onto an exposed fiber end face for cleaning without the need of physical contact such as rubbing the end face with a cleaning cloth. Figure 7C shows the jet column 118 surrounded by the low pressure zone impinging on the fiber optic end face 120 of a fiber optic male connector, i.e., plug, 113.

[0041] As schematically shown in Figure 11, the spacing of the nozzle 40 from the fiber end face during cleaning enables the concentrated cleaning jet column 118 to clean and dry a fiber optic end face that is recessed in a female connector with no physical contact

between spacer tube 30 or any other part of the cleaning device. The same cleaning nozzle is also capable of cleaning end faces that are not installed in an adapter, i.e., a fiber optic male connector as schematically shown in Figure 10. Specifically, Figure 10 shows a fiber optic male connector having a fiber optic end face being cleaned by jet column 118 with no physical contact between spacer tube 30 or any other part of the cleaning device.

[0042] The Coandă effect can be induced in both dry and "wet" gases, e.g., dry air, and air in which an atomized liquid is dispersed. Therefore, a high-purity, fast-drying solvent cleaner may be injected momentarily into the existing airstream column. This is done by opening the movable needle plug 110 to introduce solvent from a source of solvent 116 through line 119 and out inner solvent orifice 108a. The area of low pressure which forms jet column 118 (Figure 7C) is created by the Coandă effect and causes the solvent to instantly atomize into a high velocity mist of droplets within the jet column 118. The airstream and atomized solvent droplets combine to create the high velocity jet column 118 containing an atomized mist that creates mechanical fluid cleaning action that may be directed onto a fiber optic end face for non-contact cleaning. When the solvent flow is shut off by moving needle plug 110 to its closed position (leftwardly as viewed in Figure 7C) the jet column 118 is dry and serves to cause residual solvent to evaporate. Evaporation of the solvent is facilitated by the reduced pressure within jet column 118 caused by the Coandă effect and obviates the need to apply a vacuum to remove residual solvent as is required by many prior art devices.

[0043] The cleaning device dispensing nozzle 104 of Figure 7C is one embodiment of a nozzle of the present invention which, when properly spaced from the fiber optic end face, will create the desired Coandă effect streams. Variations in the dispensing nozzle illustrated in Figure 7A may be made which will also provide a similar Coandă effect.

[0044] As seen in Figures 10 and 11 the cleaning tip 30 is placed in contact with the contact face of the fiber optic connector. Thus, in Figure 10 terminal end 32a of cleaning tip 30 is seated on contact face 46b of male connector 46. In Figure 11, terminal end 32a is seated on contact face 48a of female connector 48. The cleaning tip may be dimensioned and configured to fit a particular standard configuration of fiber optic end face, ferrule and connector and so different cleaner tips maybe employed for different available fiber optic end faces and housings, both male and female connector housings. The cleaning tip may be readily mounted onto and dismounted from the nozzle of the cleaning device, for example by a threadable connection, to permit rapid changing from one cleaning tip to another. The vent openings are configured and dimensioned to provide a selected gas flow pattern for cleaning optic fiber end faces, ferrules and connectors.

[0045] In fiber optic networks, single mode glass optical fiber strands which have a diameter of about 8 micrometers, are connected by encasing the strands in protective jackets to form cables and butting two cable ends together. To do this, both terminating ends of the individual fiber optic strands are typically stripped of the jacket and are bonded and encased in the center of a rod-like ferrule.

[0046] Cleanliness of the cable connections is a critical factor in maintaining peak signal communication performance. Mated connectors are highly susceptible to microscopic amounts of contamination at each of the abutting end faces of the optical fibers. Specifically, the optical transmission capability of the junction between two optical fibers can be significantly impaired by microscopically small deposits of contamination on the polished end surfaces of the fibers. Sources of such microscopic contamination include smoke soot, dust, dirt, moisture and other ambient contaminants including oils, salts and particles transferred by contact with the skin of technicians during connector manufacture and assembly, cable installation, or job site service work. Small amounts of contamination in the form of microscopic particles or a microscopic oil haze will significantly increase light attenuation across the butted connection. As network traffic is increased by use of Wavelength Division Multiplexing (WDM) technology, the need for a clean fiber-optic end face has grown in importance. Also, as demand for signal traffic bandwidth in fiber-optic communication systems increases, the cleanliness at the fiber-optic end face is increasingly important because of increases in the laser power driving fiber-optic signals. When a high-powered laser strikes a microscopically small piece of contamination on a fiber-optic end face, the contamination may burn leaving soot or burn marks on the fiber-optic end face that can significantly degrade signal transfer through the connection.

[0047] Therefore, it is essential that connector end surfaces be cleaned before the optical fiber ends are mated to each other, and/or after they become contaminated during normal use.

[0048] Before discussing details of the specific embodiments of the present invention, an explanation of the Coandă effect is useful. The Coandă effect is named after Henri Coandă, a Romanian engineer and mathematician. Coandă noted the tendency of a jet of fluid emerging from an orifice to follow an adjacent surface, whether a flat or curved surface, and to entrain fluid from the surroundings so that a region of lower pressure develops along the jet of fluid. The Coandă effect may be understood with reference to the well-known Bernoulli principle that a fast moving jet of air has lower pressure than adjacent still or a cleaning fluid comprising slower-moving air. Aircraft wings are curved on their top surfaces so

that the air must travel faster along the top surface of the wing than along the bottom surface of the wing, thereby reducing the pressure acting on the top surface. The resulting higher pressure on the bottom surfaces of the wings generates the "lift" which enables an aircraft to fly. The Coandă effect is explained with reference to Figures 7A and 7B. A jet G of air or other gas exiting from an orifice O is moving at a velocity higher than that of the surrounding ambient atmosphere, which may be stationary. The jet G therefore, in accordance with the Bernoulli principle, has a lower pressure P_g than the pressure P_a of the ambient atmosphere. In Figure 7A, the pressure of the ambient atmosphere, e.g., atmospheric pressure, is indicated by the arrows P_a and is seen to act on the entire outer circumference of the jet G. In contrast, as shown in Figure 7B, if the jet G is discharged adjacent to a surface S of a structure T, the structure T blocks the ambient air pressure P_a from acting on one side of the jet G, so that the unblocked ambient pressure P_a forces the jet G into contact with surface S. Even if the surface S is curved or bent as shown in Figure 7B, ambient pressure P_a forces the jet G to follow the contour of the surface S. The Coandă principle is applied in various fields such as air foils (aerodynamics), gas burner flare tips and film blowing.

[0049] The present invention utilizes the Coandă effect to have a cleaning fluid comprising a gas flow of a solvent-containing cleaning jet and then a no-solvent drying jet of gas be directed at, adhere to, and follow the contour of ferrule end faces and any surrounding enclosing structure without need of physical contact of the cleaning device itself with the end faces of the fiber optic structures to be cleaned. In order to attain the Coandă effect, the gas flow is directed over the tapered, pointed needle plug described herein, care must be taken to aim the gas flow accurately, and to distance the nozzle from which the gas flow emanates at a proper stand-off distance between the sharp tip of the needle plug and the surfaces to be cleaned. The cleaning device of the present invention enables meeting these objectives, in particular attainment of the proper stand-off distance.

[0050] Maintaining a proper stand-off distance between the needle plug tip and the end face or other surface being cleaned is highly desirable as it enhances the cleaning effect and reduces the time required for both the solvent cleaning period and the drying period. The cleaning tip of the present invention enables maintaining the proper stand-off distance.

[0051] Referring now to Figure 8, a cleaning tip 30 in accordance with an embodiment of the present invention comprises a spacer tube 32 having a terminal end 32a and comprised of a tube wall 32b. Spacer tube 32 has one or more vent openings 34 (only one is shown in Figure 8) to permit gas flow to exit the cleaning tip 30 after impinging on the end face or other surface or surfaces to be cleaned. In the embodiment illustrated in Figure 8,

with cleaning tip 30 mounted on cleaning device 38, terminal end 43a extends into vent opening 34 and occludes a segment S of its length. Cleaning tip 30 further comprises a mounting base 36 having internal threads 36a and a base contact surface 36b.

[0052] A partial view of a cleaning device 38 shows nozzle end 40 of device 38 having a seating surface 40a and a tapered needle 42 which terminates in a sharp pointed needle tip 42a. Needle 42 is contained within a tubular needle housing 43 which has a terminal end 43a and which shields needle 42. Needle housing 43 has a mounting pedestal 44 having external threads 44a which are adapted to receive internal threads 36a of mounting base 36, so that cleaning tip 30 may be mounted on the nozzle end 40 of cleaning device 38 by screwing mounting base 36 onto mounting pedestal 44 to seat base contact surface 36b firmly in contact with seating surface 40a. The outside diameter of needle housing 43 is dimensioned to be received within the inside diameter of spacer tube 32.

[0053] With cleaning tip 30 so mounted on the nozzle end 40 of cleaning device 38, a distance d is provided between needle tip 42a and terminal end 32a of spacer tube 32. In use, terminal end 32a is placed so that it contacts either the housing end that supports the ferrule of a male end face (as shown in Figure 10), or the coupling of a female end face (as shown in Figure 11). The cleaning tip 30 thus contacts the internal alignment surfaces that are part of the coupling geometry. This allows the cleaning tip to establish a proper stand-off distance without ever actually coming in direct contact with a fiber optic end face to be cleaned. The cleaning tip 30 is appropriately dimensioned to provide the desired stand-off distance d (Figure 8). A number of cleaning tip variants may be provided with spacer tubes of different lengths to provide selected stand-off distances for different standard optic fiber connectors. The same size mounting base 36 may be provided in each case so that each differently sized cleaning tip variant may be mounted on a standard mounting pedestal 44.

[0054] Spacer tube 32 has an outside diameter D (Figure 8) which is selected to fit into standard size ferrule openings. Outside diameter D , like the length of spacer tube 32, may be varied to provide cleaning tips of different diameter and/or length to fit standard size ferrule openings and to provide a desired stand-off distance. The cleaning tip directs the Coandă gas flow onto the fiber connector end face, thus directing solvent and air for non-contact cleaning of a fiber optic end face, as described in the '601 Application.

[0055] The functions of the cleaning tip are as follows.

To provide a simple fixture to position the nozzle outlet needle tip so the desired stand-off distance from the outlet needle tip to the fiber end face being cleaned by the gas flow is easily established and maintained.

To ensure the connector end face (and nearby associated connector surface areas) being cleaned are consistently clean and dry at the end of a single cleaning cycle.

Aligns the gas flow with the optic fiber end face so it is centrally positioned within the gas flow during the cleaning cycle.

[0056] Cleaning tip 30 may be configured with spacer tube 32 in the shape of a cylinder to make insertion of cleaning tip 30 into a standard connector coupling interconnect non-directional. Therefore, no special orientation of cleaning device 38 is needed when inserting the cleaning tip 30 prior to commencing cleaning.

[0057] Alternatively, the spacer tube of cleaning tip 30 may be configured in a non-circular cylindrical shape and size to be optimized for cleaning MPO type connectors, or other specialty type connectors. Such non-circular cylindrical configurations may make orientation of the cleaning device relative to the connector being cleaned necessary for a proper fit into specialty couplings engineered end faces (not illustrated).

[0058] Different size cleaning tips 30 may be engineered to clean specific sizes of connectors. All cleaning tip variants are interchangeable on the mounting pedestal 44 to allow one cleaning device to clean a wide variety of connector sizes, with specifically sized cleaning tips for any specific connector size being cleaned.

[0059] The spacer tube 32 allows cleaning of both female and male connector ends of the same size connector with the same cleaning tip. (As an example, a cleaning tip may be sized to clean a 1.25mm (LC Style) connector and that same cleaning tip will clean both male and female end face configurations.)

[0060] The capability of one cleaning tip fixture to clean both male and female connectors is unique because commonly used connector end face cleaning methods require use of a specific size connector cleaner (for example a cleaner for a 1.25 mm LC connector) to clean a male connector end face, and a different fixture or method is required to clean the mating side female connector end face.

[0061] Figures 9A, 9B and 9C respectively show three versions of the spacer tube, 32x, 32y and 32z, each having a different configuration of vent openings. Figure 9A shows spacer tube 32x and its mounting base 36x. Spacer tube 32x has four vent openings 34x of equal size. The un-numbered crossed arrows of Figure 9A show the resulting gas flow pattern through the four vent openings 34x. Figure 9B shows spacer tube 32y and its mounting base 36y and Figure 9C shows spacer tube 32z and its mounting base 36z. Figure 9B shows corresponding features of the two vent openings 34y and Figure 9C shows four vents 34z, two of which are wide vent openings and two of which are narrow vent openings. The use of

vent openings in the cleaning tip provides additional means of controlling pressurized gas flow onto and across the end face being cleaned. Vent openings also establish uniform flow of exhaust gas flow away from the end face during the cleaning process.

[0062] Vent openings may be positioned at 3, 6, 9 and 12 o'clock (Figure 9A) to allow uniform four-way gas flow across the end face during cleaning. This type of venting is ideal when cleaning an end face that is both concave and round in shape, or an expanded beam lens.

[0063] Vent openings may be positioned at only 3 and 9 o'clock (Figure 9B) to direct gas flow longitudinally across the end face during cleaning. This type of venting is ideal when cleaning connectors that are concave and rectangular in shape such as an MPO connector.

[0064] Vent openings may vary in size (Figure 9C) to manage gas flow so there are primary and secondary gas flow paths, to ensure no gas flow dead zones which may result in incomplete cleaning. The four vent openings 34z illustrated in Figure 9C allow unrestricted gas flow in four directions exhausting out of the cleaning tip 32z. In all cases, the open terminal end 32a of spacer tube 32 (Figure 8) provides a primary outlet for the cleaning fluid to impinge on the fiber optic end face and any surrounding structure being cleaned.

[0065] The length (L in Figure 8) of the vent openings 34 in a cleaning tip spacer tube 34 is not less than the distance between the terminal end 43a of the needle housing 43, and the terminal end 32a of the cleaning tip 30. The vent openings 34 should be elongated and of a width and length establishing an opening area sized between 30% and 70% of the total outside surface area of the spacer tube 32. The vent openings may be of a length that starts at or immediately adjacent to the terminal end 32a of the spacer tube 32, and overlaps a portion (S) in Figure 8 of needle housing 43 to better manage and optimize gas stream exhaust from vent openings 34 during the cleaning cycle.

[0066] The mounting base 36 (Figure 8) is used to attach cleaning tip 30 to mounting pedestal 44 by being threaded onto it. This permits a secure mount of cleaning tip 30 to cleaning device 38 and also permits quick changeout of cleaning tips 30 of various sizes to clean different sizes and types of fiber connector end faces.

[0067] An annular channel 43b of needle housing 43 surrounds needle plug 42 and cleaning fluid is introduced via dry gas passageway 106 during a drying period and solvent is introduced via solvent passageway 108, see Figure 7C. The passageways 106, 108 are schematically indicated by arrows A and B in Figure 8. The cleaning fluid flows from annular

channel 43 through spacer tube 32 and into contact with the fiber optic end face being cleaned.

[0068] The cleaning tip diameter (D in Figure 8) of a given cleaning tip will be sized to accommodate the size of the connector being cleaned. For example, connectors with a 1.25mm, 1.6mm, 2.0mm and 2.5 mm diameter end face will use a cleaning tip diameter appropriately sized to fit within the size of the associated fiber coupling to permit cleaning female connectors as shown in Figure 11, discussed below.

[0069] Figure 10 schematically illustrates an unmated male fiber optic connector 46 that is positioned on the cleaning tip 30 to allow the fiber optic end face 46a to be in direct contact with gas flow 118 during cleaning. The cleaning tip 30 ensures the fiber end face 46a is at the optimum distance and orientation to the gas flow 118 during cleaning. For example, the four vents 34x in Figure 9A allow unrestricted airflow in four directions to ensure a clean and dry end face at the end of the cleaning cycle. Optic connector 46 has a contact face 46b against which terminal end 32a of spacer tube 32 is seated. This provides the proper stand-off distance between the tip 42a of needle 42 (Figure 8) and end face 46a.

[0070] Figure 11 illustrates a fiber optic connector 46 mounted in a fiber optic coupling 48 that is used for mating two fiber end faces. The fiber end face 46a is recessed in the coupling 48 but the cleaning tip 30 allows direct contact with gas flow 118 during cleaning. Seating terminal end 32a of spacer tube 32 against contact face 48a of coupling 48 ensures that when the fiber end face 46a is mounted in a fiber optic coupling 48, the fiber end face 46a is at the optimum distance from the tip of needle 42 and proper orientation in the gas flow 118 to ensure proper cleaning.

[0071] The present invention has been described in detail with respect to specific embodiments thereof but these specific embodiments are not intended to be construed as limitations on the scope of the invention.

THE CLAIMS

What is claimed is:

1. A cleaning tip for the nozzle of a cleaning device, the nozzle having a nozzle outlet from which a cleaning fluid is emitted for cleaning a fiber optic end face juxtaposed to the nozzle outlet, such fiber optic end face being disposed in a housing member having a housing member contact face, the cleaning tip being dimensioned and configured to have such cleaning fluid flowed therethrough, the cleaning tip comprising:

a spacer tube having a tube wall having an open terminal end and an opposite base end, and a mounting base disposed at the base end, the mounting base being dimensioned and configured to mount the cleaning tip on such nozzle in fluid flow communication with such nozzle outlet, whereby such cleaning fluid discharged from such nozzle outlet is flowed through the cleaning tip to impinge on such fiber optic end face;

the tube wall having one or more vent openings therein to provide an exhaust outlet from the cleaning tip for such cleaning fluid; and

the spacer tube being dimensioned and configured to provide a preselected stand-off distance between such nozzle outlet and such fiber optic end face when the terminal end of the spacer tube is placed in contact with such housing member contact face.

2. The cleaning tip of claim 1 comprising a plurality of vent openings disposed circumferentially about the spacer tube.

3. The cleaning tip of claim 2 wherein the spacer tube has an outer surface area and the total area of one or more vent openings comprises from about 30% to about 70% of the outer surface area.

4. The cleaning tip of any one of claims 1, 2, or 3 wherein the cleaning tip is dimensioned and configured to be removably mounted on such nozzle.

5. The cleaning tip of claim 4 wherein the mounting base is threaded and is threadably mounted on the nozzle.

6. An assembly of (a) a cleaning device nozzle having a mounting pedestal thereon, and a nozzle outlet through which a cleaning fluid is impinged on a fiber optic end face juxtaposed to the nozzle outlet, the fiber optic end face being disposed in a housing member having a contact face, and (b) a cleaning tip mounted on the nozzle;

a needle plug movably disposed in the nozzle outlet to regulate flow of such cleaning fluid through the nozzle outlet, the needle plug diminishing in cross section in the direction of outward flow from the nozzle and terminating in a point;

the cleaning tip being dimensioned and configured to have such cleaning fluid flowed therethrough over the needle plug, the cleaning tip comprising a spacer tube having a tube wall having a terminal end and an opposite base end, and a mounting base at the base end, the mounting base being mounted on the mounting pedestal with the needle plug disposed within the cleaner tip and the cleaner tip disposed in fluid flow communication with the nozzle outlet; and

the tube wall having one or more vent openings therein to define a flow path for such cleaning fluid from the nozzle outlet through the cleaner tip and out the vent opening.

7. The assembly of claim 6 comprising a plurality of vent openings disposed circumferentially about the spacer tube.

8. The assembly of claim 7 wherein the spacer tube has an outer surface area and the total area of the one or more vent openings comprises from about 30% to about 70% of the outer surface area.

9. The assembly of any one of claims 6, 7, or 8 wherein the mounting base is removably mounted on the mounting pedestal.

10. The assembly of claim 9 wherein the mounting base and the mounting pedestal have respectively complementary threads and the mounting base is threadably mounted on the mounting pedestal.

11. The assembly of any one of claims 6, 7, or 8 wherein the nozzle further comprises a needle plug housing within which the needle plug is disposed, the needle plug housing being disposed within the spacer tube so as to occlude at most a portion of the vent openings.

12. The assembly of claim 11 wherein the needle plug housing is slidable within the spacer tube.

13. The assembly of claim 12 wherein the needle plug housing is a slidable snug fit within the spacer tube.

14. The assembly of claim 11 wherein the nozzle outlet is dimensioned and configured to flow such cleaning fluid through the needle plug housing and over the needle plug.