

Fiber Optic Connector End Face Quality and Maintenance

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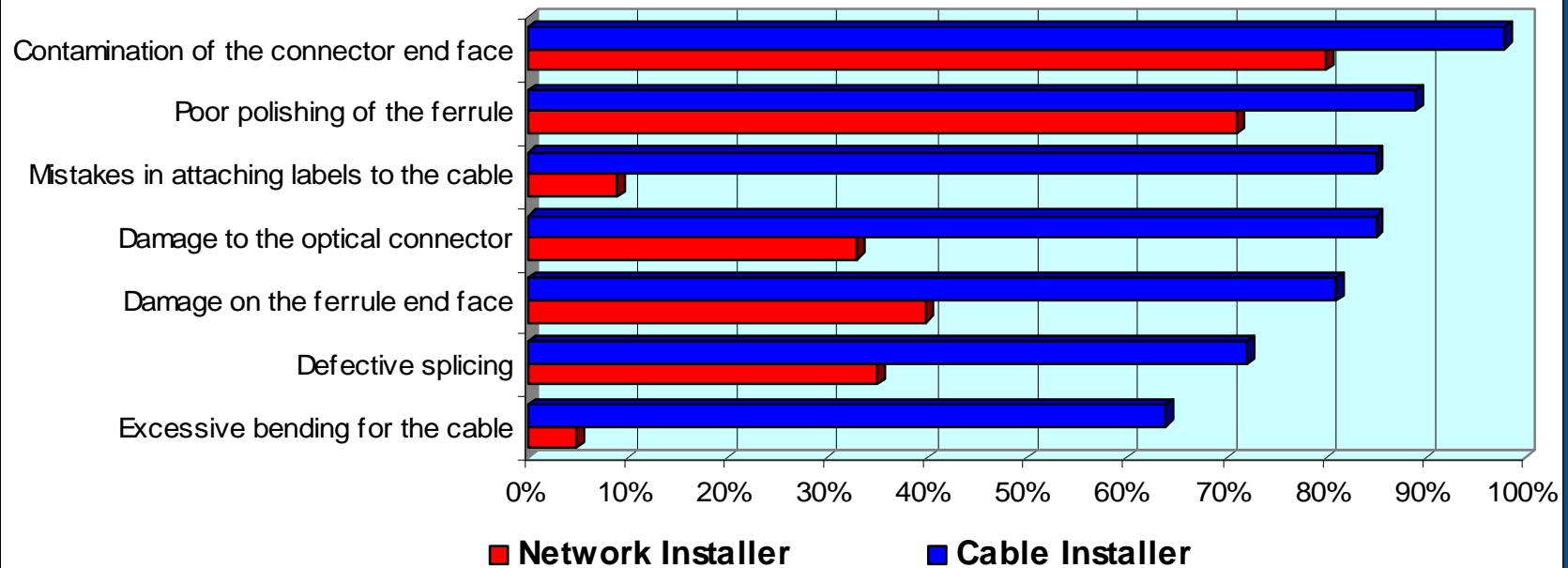
The table below is a summary of six case studies done with companies with advanced IT organizations.

Annual Downtime Cost: Productivity vs. Revenue			
Case Study	Annual Revenue	Downtime Cost	Cost/Hour
Energy	\$6,750,000,000	\$4,300,000	\$1,624
High Tech	\$1,300,000,000	\$10,200,000	\$4,167
Health Care	\$44,000,000,000	\$74,600,000	\$96,632
Travel	\$850,000,000	\$2,400,000	\$38,710
Finance (US)	\$4,000,000,000	\$10,600,000	\$28,342
Finance (EU)	\$1,200,000,000	\$379,000	\$1,573

The data in the table is from a study called "The Cost of Enterprise Downtime 2003" conducted by Infonetics Research



Causes for Network Failures



In a recent study by NTT-Advanced Technology, 98% of cable installers and 80% of network owners reported contamination being the root cause of a network failure.

Important Standards Regarding End Face Quality and Cleaning

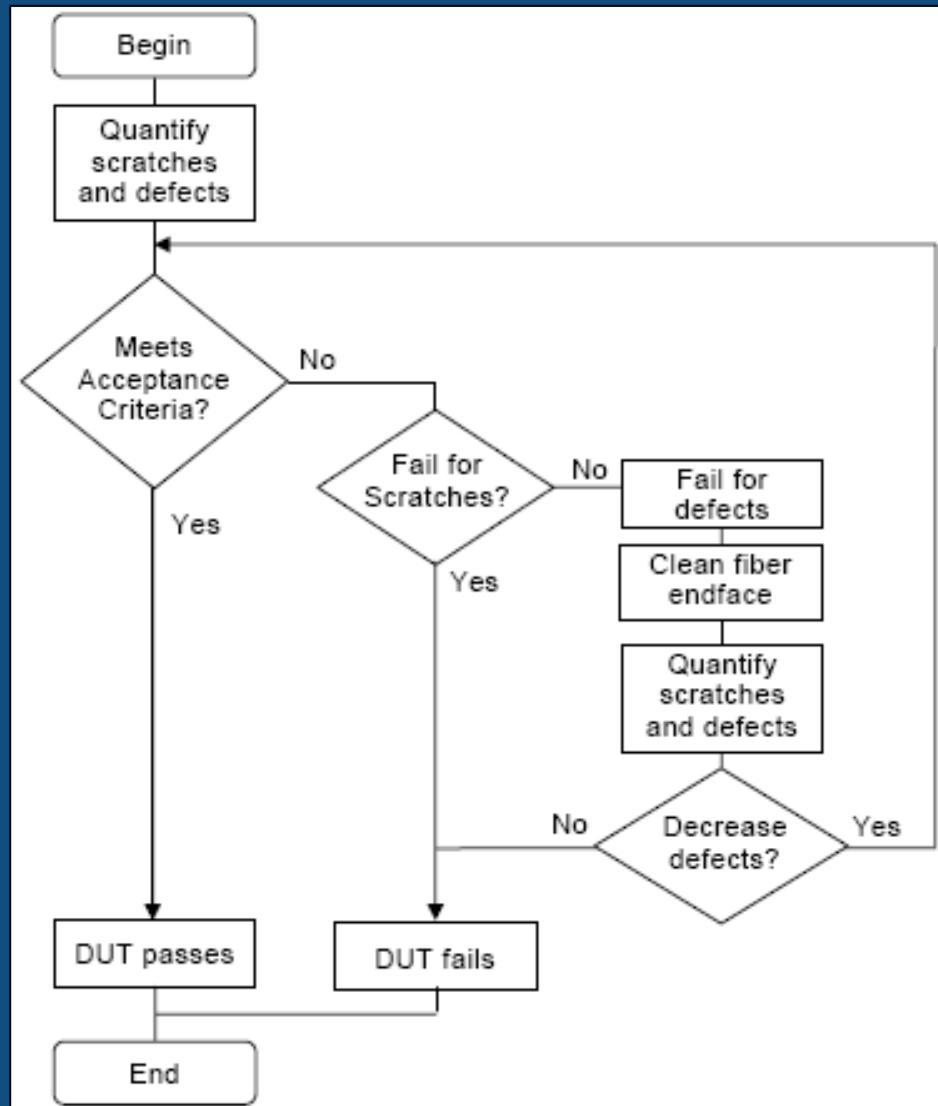
- IEC 61300-3-35 è Fibre Optic Interconnecting Devices and Passive Components – Basic Test and Measurement Procedures
- IPC 8497-1 è Cleaning Methods and Contamination Assessment for Optical Assembly
- IEC 62627 (DTR) è Fibre Optic Interconnecting Devices and Passive Components – Fibre Optic Connector Cleaning Methods

- IEC 61300-3-3 has developed zones for setting requirements for connector's endface quality.

Single Fiber Connectors	Zone	Diameter for Singlemode	Diameter for Multimode
	A: Core	0 μ m to 25 μ m	0 μ m to 65 μ m
	B: Cladding	25 μ m to 120 μ m	65 μ m to 120 μ m
	C: Adhesive	120 μ m to 130 μ m	120 μ m to 130 μ m
	D: Contact	130 μ m to 250 μ m	130 μ m to 250 μ m
Multi Fiber (MT) Connectors	Zone	Diameter for Singlemode	Diameter for Multimode
	A: Core	0 μ m to 25 μ m	0 μ m to 65 μ m
	B: Cladding	25 μ m to 120 μ m	65 μ m to 120 μ m

- All data above assumes a 125 μ m cladding diameter
- Multimode core diameter is set at 65 μ m to accommodate all common core sizes in a practical manner
- A defect is defined as existing entirely within the inner most zone which it touches

Inspection procedure flow from IEC 61300-3-35



IEC 61300-3-3 Sect 5.4 Visual Requirements

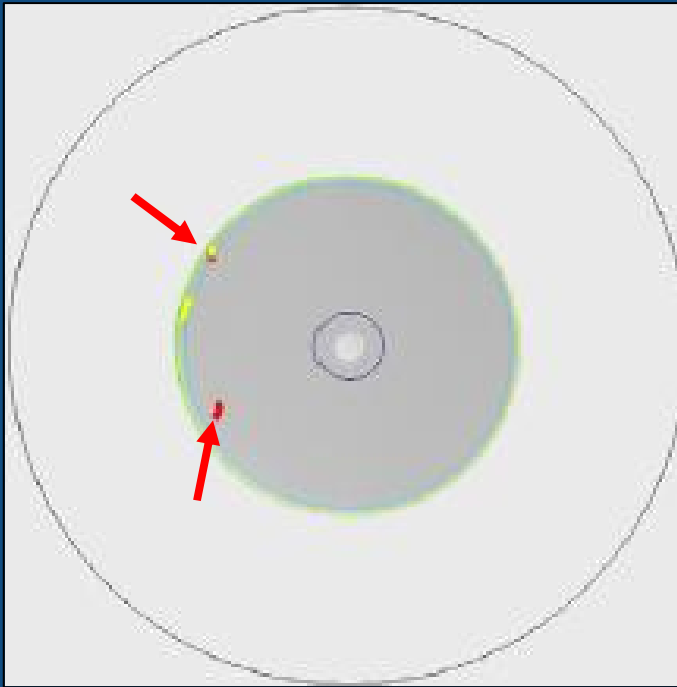
- Scratches requirement refers to width
- Visible sub-surface scratches in core and cladding are NOT allowed
- All loose particles must be removed
- If defects are not removable, the defect must be within the criteria to be acceptable for use
- There are no requirements for the area outside of the contact zone since defects in this area have no influence on the performance
- Cleaning loose debris beyond the contact region is recommended good practice

IEC 61300-3-3 Sect 5.4 Visual Requirements

Singlemode PC RL ≥ 45 dB		
Zone	Scratches	Defects
A: Core	None	None
B: Cladding	No Limit $\leq 3\mu\text{m}$ None $> 3\mu\text{m}$	No limit $< 2\mu\text{m}$ 5 from $2\mu\text{m}$ to $5\mu\text{m}$ None $\geq 5\mu\text{m}$
C: Adhesive	No limit	No limit
D: Contact	No limit	None $\geq 10\mu\text{m}$

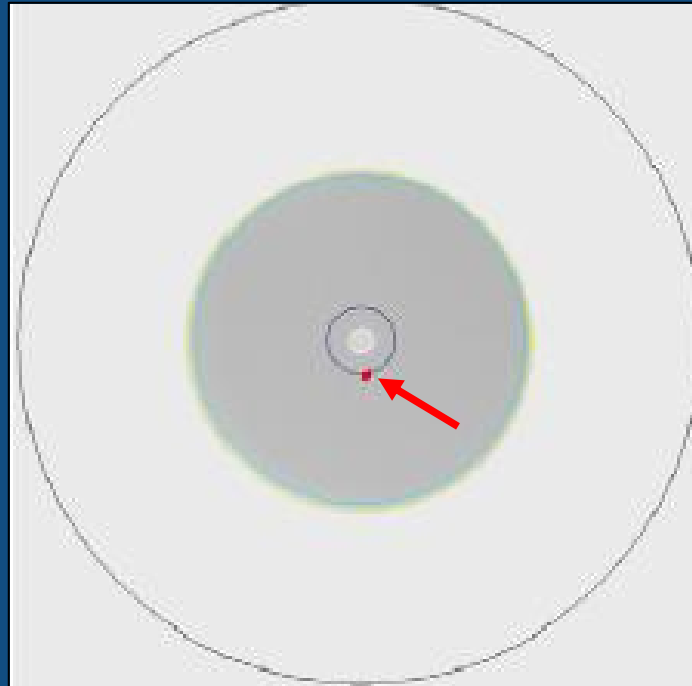
IEC 61300-3-3 Sect 5.4 Visual Requirements

Singlemode PC RL ≥ 45 dB – Low Resolution Images



Failed:

Defects are $> 5\mu\text{m}$

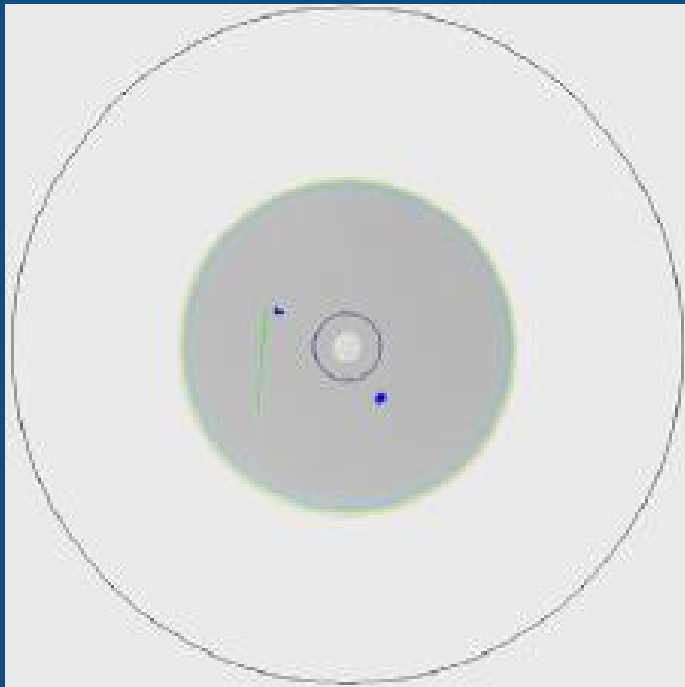


Failed:

Defect is touching the core

IEC 61300-3-3 Sect 5.4 Visual Requirements

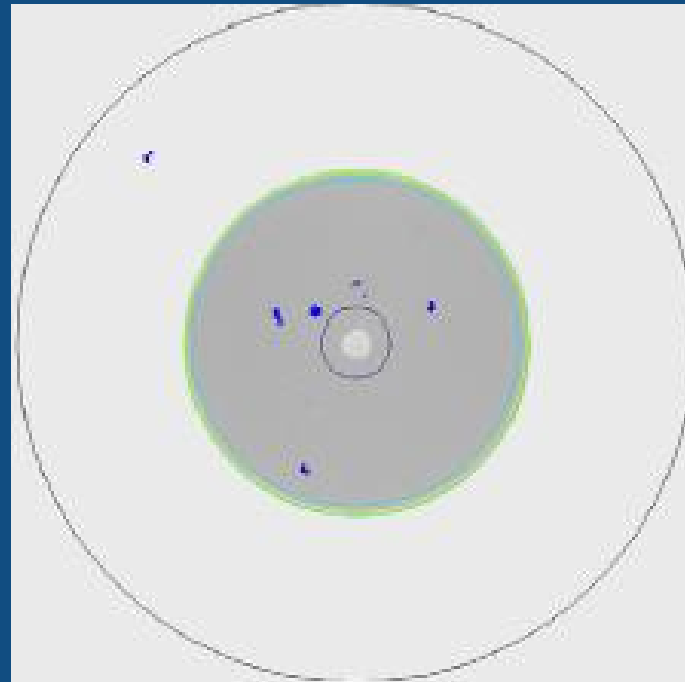
Singlemode PC RL ≥ 45 dB – Low Resolution Images



Passed:

Scratch is fine

Two particles are $< 5\mu\text{m}$



Passed:

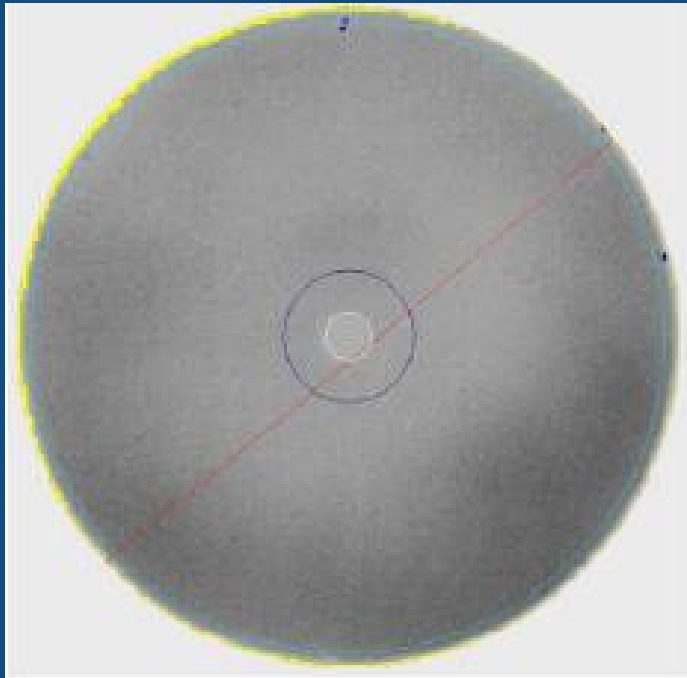
One defect is $< 2\mu\text{m}$ in cladding - ignore

Five are $< 5\mu\text{m}$ in cladding

One defect $< 10\mu\text{m}$

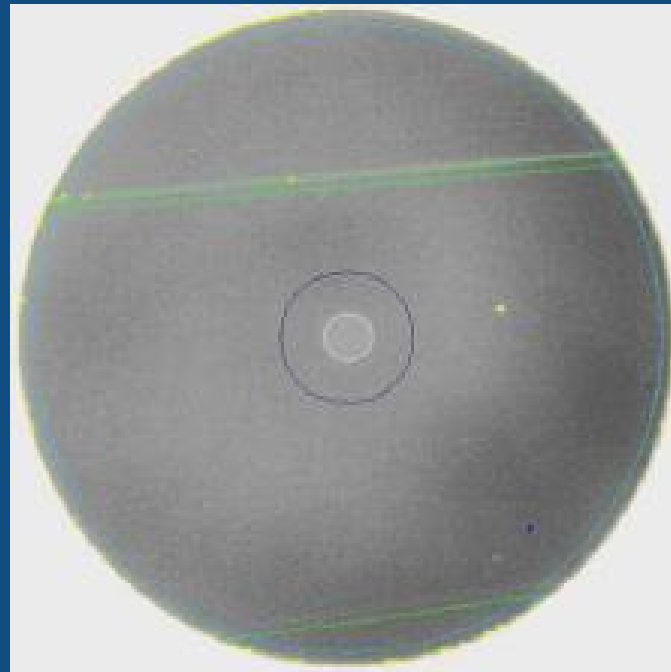
IEC 61300-3-3 Sect 5.4 Visual Requirements

Singlemode PC RL ≥ 45 dB – High Resolution Images



Failed:

Scratch is in the core zone



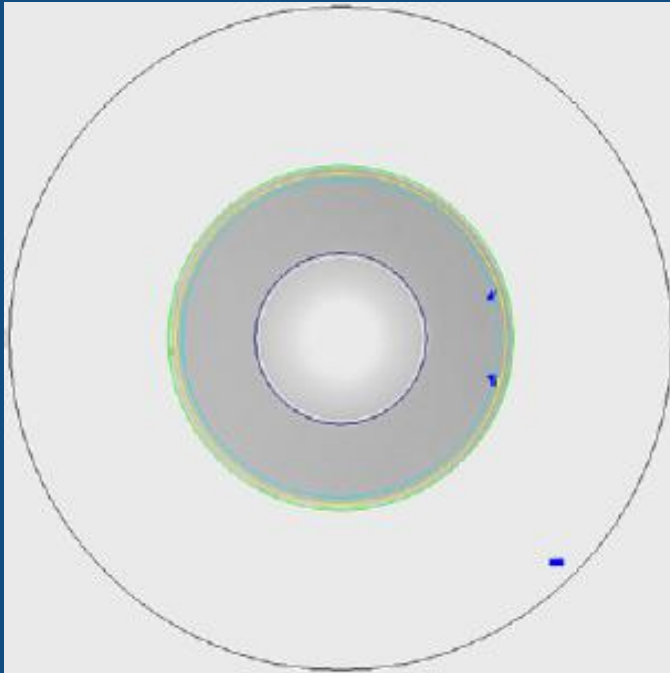
Passed:

Scratches are in the cladding
Defects are $< 2\mu\text{m}$

IEC 61300-3-3 Sect 5.4 Visual Requirements

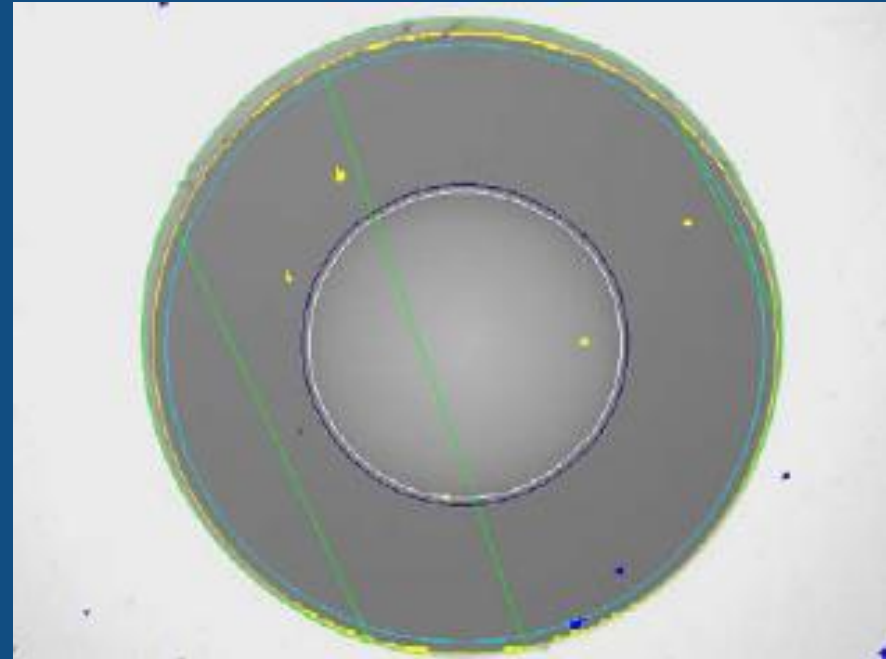
Multimode PC RL \geq 45dB		
Zone	Scratches	Defects
A: Core	None	$4 \leq 5\mu\text{m}$ None $> 5\mu\text{m}$
B: Cladding	No Limit $\leq 5\mu\text{m}$ None $> 5\mu\text{m}$	No Limit $< 2\mu\text{m}$ 5 from $2\mu\text{m}$ to $5\mu\text{m}$ None $\geq 5\mu\text{m}$
C: Adhesive	No limit	No limit
D: Contact	No limit	None $\geq 10\mu\text{m}$

IEC 61300-3-3 Sect 5.4 Visual Requirements



Passed:

2 defects $< 5\mu\text{m}$ in cladding
1 defect in contact zone



Passed:

1 fine scratch $< 1\mu\text{m}$ in cladding
2 defects $< 5\mu\text{m}$ in core
2 fine scratches $< 5\mu\text{m}$ in cladding
 $< 5\mu\text{m}$ defects in cladding

- IEC 62627 – DTR scope is intended to:

“...to emphasize the need for cleaning fibre optic connectors as well as describing the some of the current tools and methods for proper cleaning.”

- IPC-8497-1 scope is intended to:

“...to describe the methods of inspecting and cleaning all optical interfaces so their interconnectivity does not result in loss of optical signal..”

In summary, the IPC-8497-1 is a summary of both IEC standards

The IPC document was a development of the following companies:

- Flextronics
- Nortel
- Cisco Systems
- Celestica
- US Conec
- JDS Uniphase
- Nat'l Inst. Of Standards & Technology
- Avanex
- MicroCare
- EPTAC Corp
- Alcatel-Canada
- Aerotek
- Conjunction with TIA FO-4.3.2



IEC 62627 Sect 3.2.1

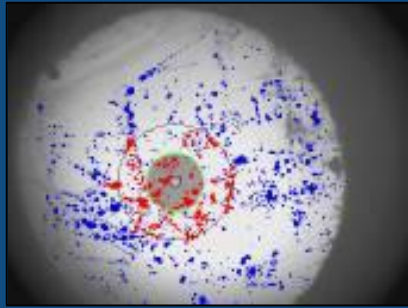
- “With increased data rates, it has become increasingly important to assure that all connectors are inspected and if necessary cleaned before making the connection. “
- “ New connectors must be inspected and if necessary cleaned as well. Inspect and clean every connection, every time is the best assurance of a reliable optical network.”

Why clean fiber optic connectors???

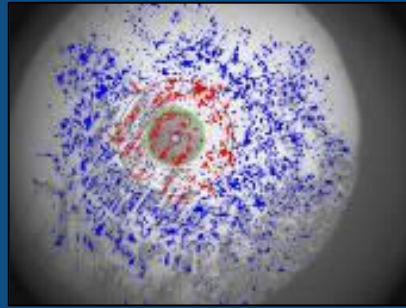
Debris can cause significant back reflection, insertion loss and fiber damage

Where does debris come from according to IEC 61627?

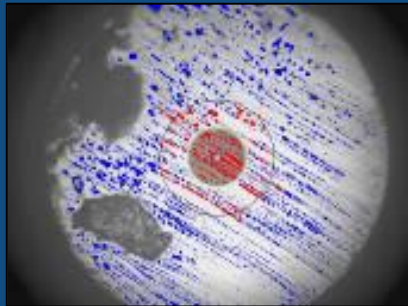
- Mishandling
 - Ø Most common source of contamination
 - Ø Accidental touching – skin oil or hand lotion
 - Ø Lint generated from fabrics
- Environmental sources
 - Ø Saw dust, sheet rock and paint fumes from construction
 - Ø Dry climates = dust in the air
 - Ø Humid climates = airborne contaminants condense on endface
- Contamination travels
- Contamination migration



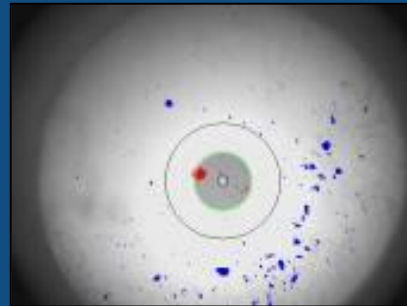
Dust Particles



Hand Lotion



Finger Prints



Alcohol Residue

Common Contaminants

- Dust
- Skin oil
- Alcohol residue
- Distilled water residue
- Vegetable oil
- Hand lotion
- Dryer lint
- Saltwater residue
- Graphite

Common sources of residue contamination:

- Accidental contact with an installer's fingers
 - Example: Human skin oil
 - Example: Hand lotion
 - Example: Vegetable oil from fried foods
- Droplets of oil lubricant used for propellants in compressed air
- Cleaning solvent residues
 - Example: Poor wiping technique by technician
 - Example: Using liquids that are hygroscopic
 - Example: Distilled water rinsing
 - Example: Salt water moisture
- Material oils result from the outgassing of protective end caps
- Carbonated beverages on the work site

Connector End Caps = Contamination Source.

Patch cords equipped with end caps do not guarantee a clean connector! Connector end caps are often produced with materials which can lead to end face contamination

- PVC softened with plasticizers is one of the most common end cap materials: These plasticizers can leach out from the PVC and transfer to the connector endface. Outgassing contamination is also a major concern if the assembly is exposed to high temperature
- Carbon black (graphite) is a common colorant for plastic endcaps. The graphite material is easily removed from the surface of the endcap and can become a source of contamination

IEC 62627 Sect 3.3.4 – Contamination Migration



Connector A
Before Mating



Connector B
Before Mating

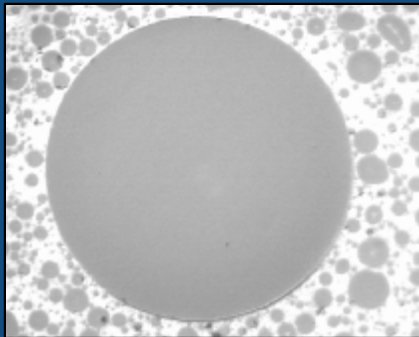


Connector A
After Mating

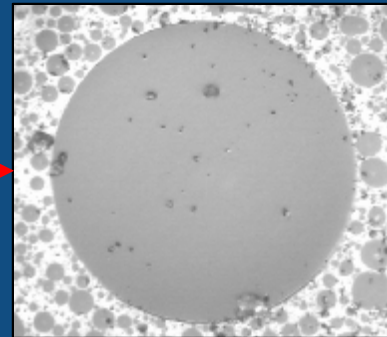


Connector B
After Mating

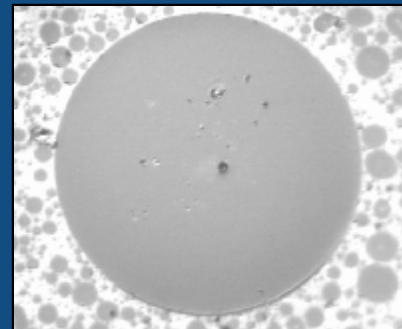
Initial Clean Endface



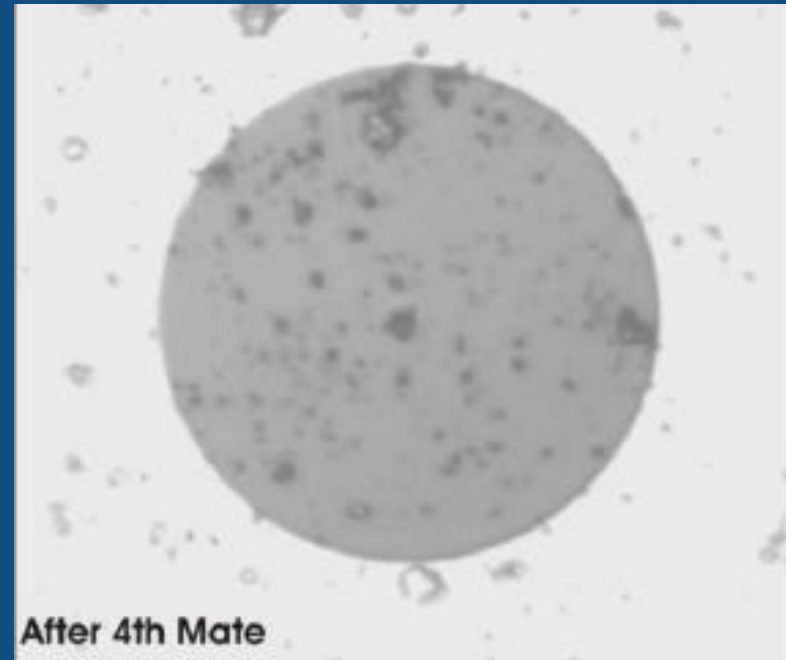
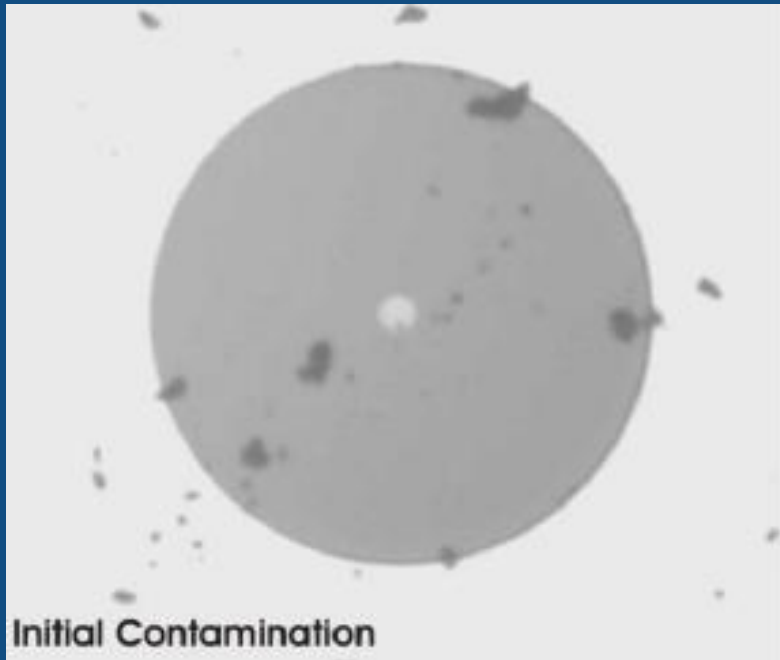
Contaminated Endface



Mated 5 times dirty then cleaned
results in severe permanent damage



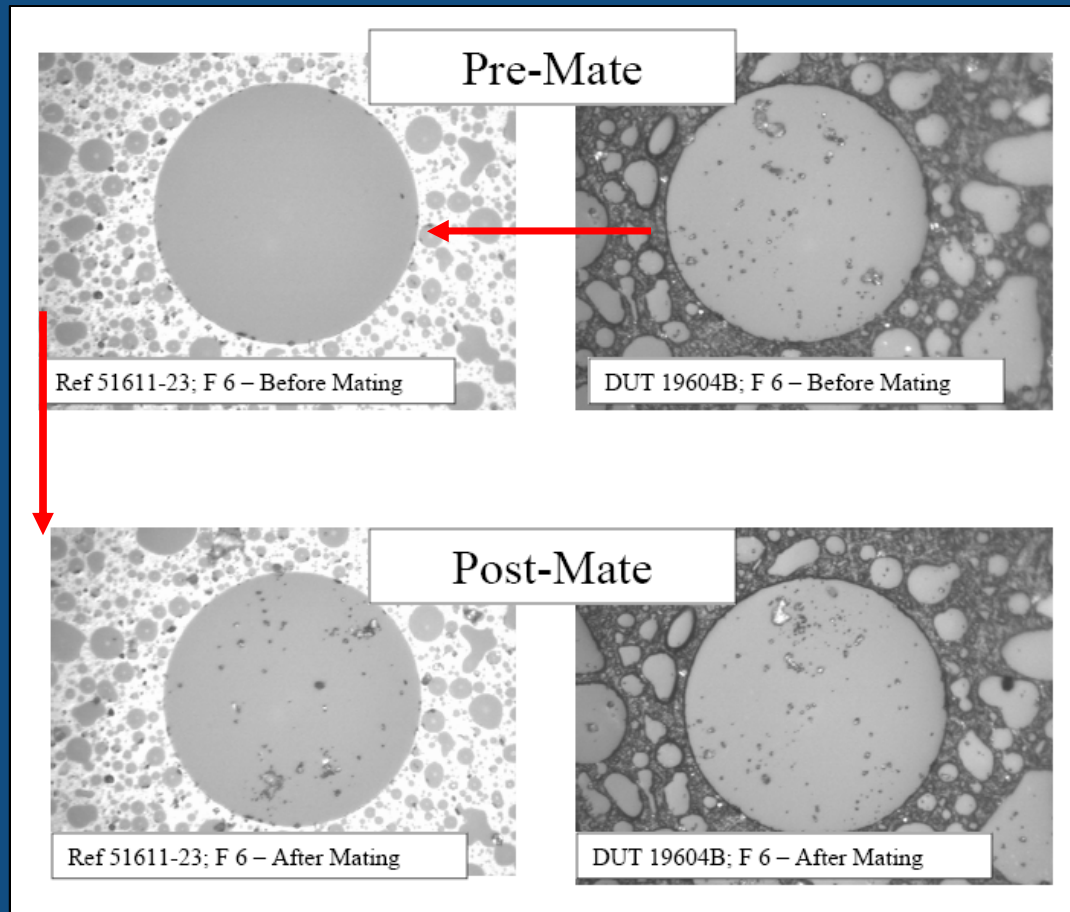
IEC 62627 Sect 3.3.4 – Contamination Migration



Contamination tends to migrate towards the fiber core after repeated mating.

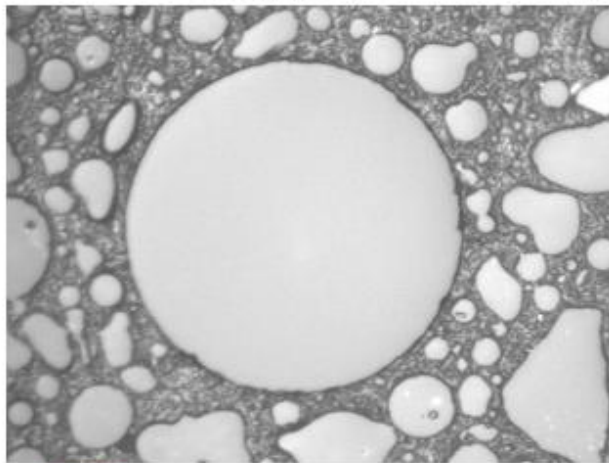
Dust particulates separate and break into fine pieces.

Dry Contamination Transfer on a MT Ferrule

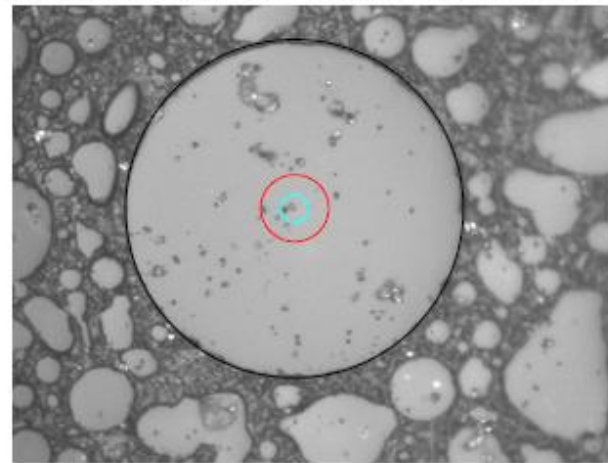


Signal Degradation Due to Contamination

Clean DUT



Contaminated DUT (Arizona Road Dust)



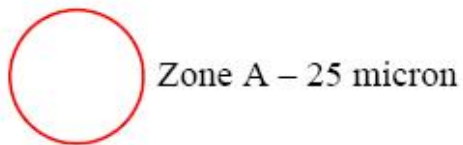
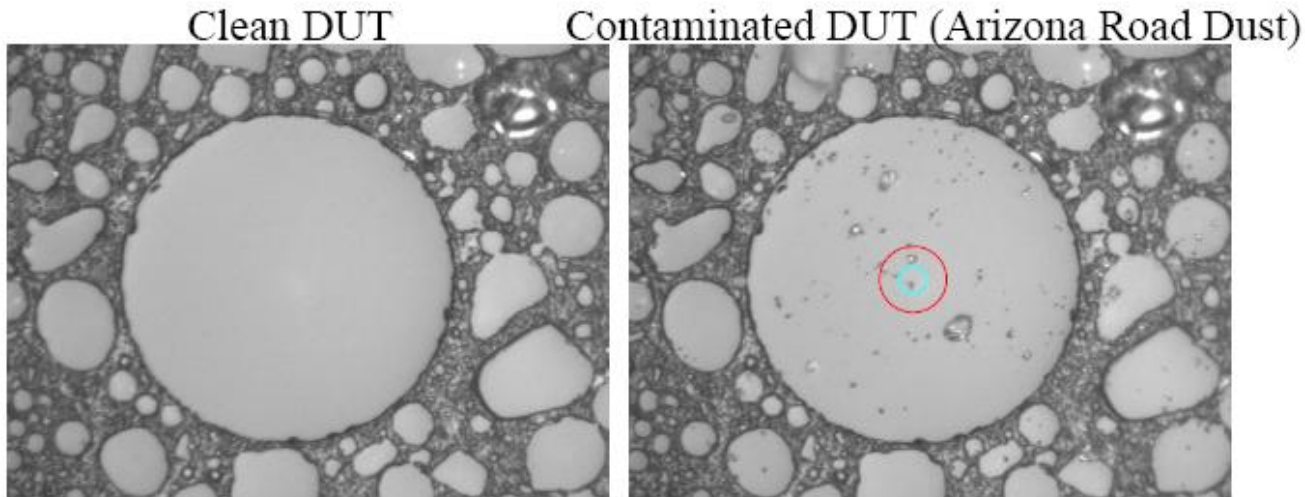
Zone A – 25 micron



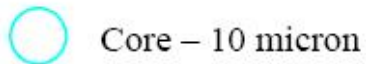
Core – 10 micron

611-23 Ref – 604B DUT; F6 D1		IL (dB)	RL (dB)
clean	average (10X)	0.098	69.4
	std deviation	0.013	0.7
	average + 3X std dev	0.137	67.4
Contaminated		0.430	33.4

Signal Degradation Due to Contamination



Zone A – 25 micron



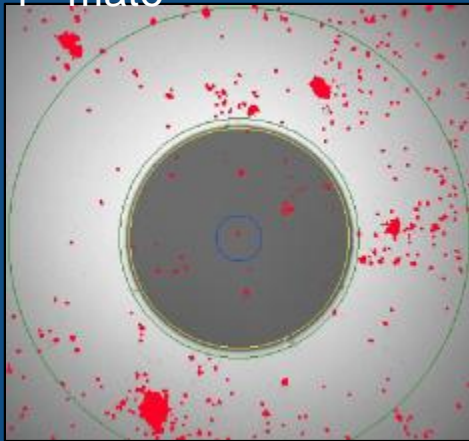
Core – 10 micron

695B Ref – 602B DUT; F6 D1		IL (dB)	RL (dB)
clean	average (10X)	0.131	72.9
	std deviation	0.028	1.6
	average + 3X std dev	0.214	68.1
Contaminated		0.150	51.8

Particle Migration

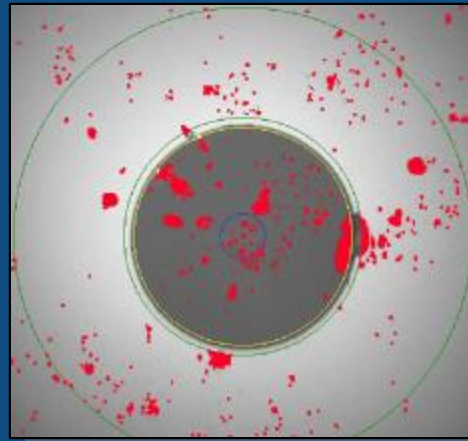
Contaminated LC

1st mate



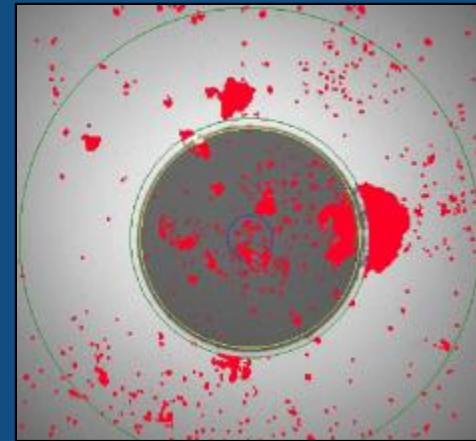
Contaminated LC

3rd mate



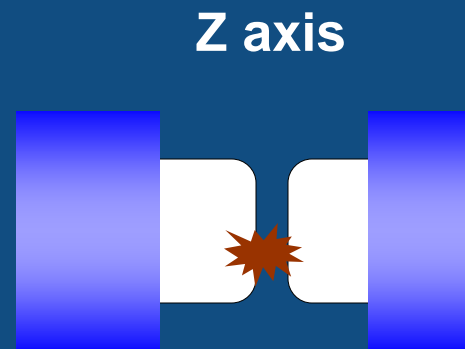
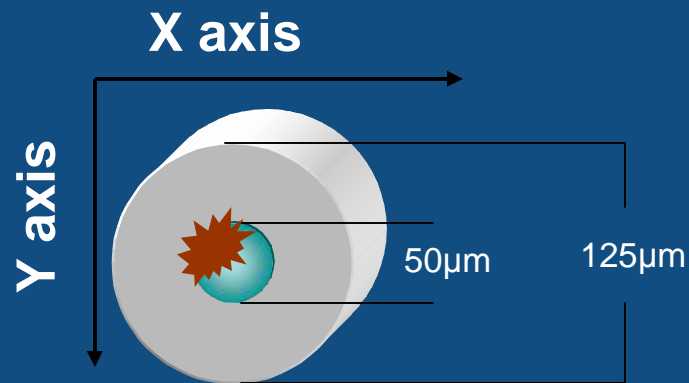
Contaminated LC

5th mate



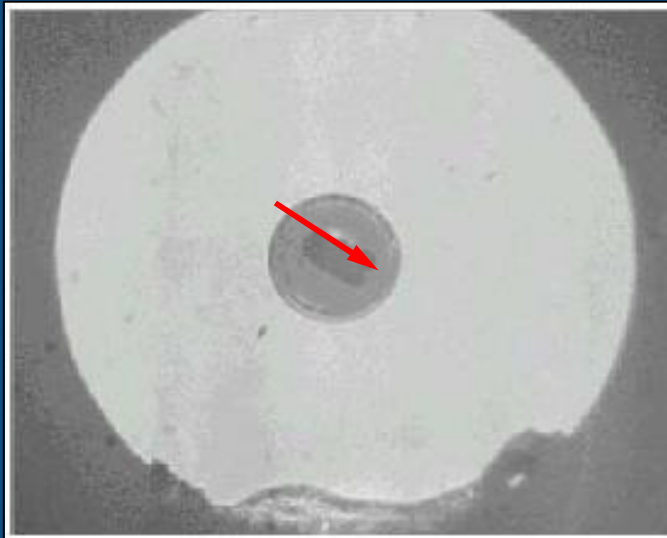
Contamination away from the core can be re-distributed during matings and frequently gravitates toward the core due to static charge buildup.

[Berdinskikh, Chen, Culbert, Fisher, Huang, Roche, Tkalec, Wilson, Ainley;
“Accumulation of Particles Near the Core During Repetitive Fiber Connector
Matings and De-matings” OFC/NFOEC 2007, NThA6]

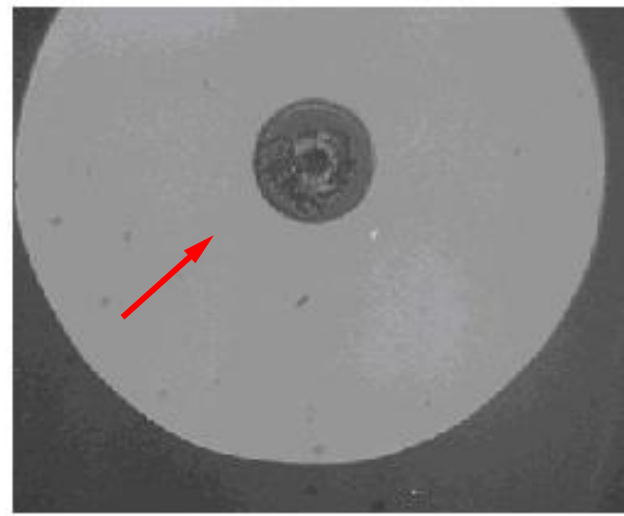


Contamination can block the light propagating between the fiber cores (X,Y axis) or disrupt uniform contact (Z axis) between mating ferrules.

These are images of effects of actual connector end faces that were contaminated in high power applications (>1W)



The fiber core flaked away

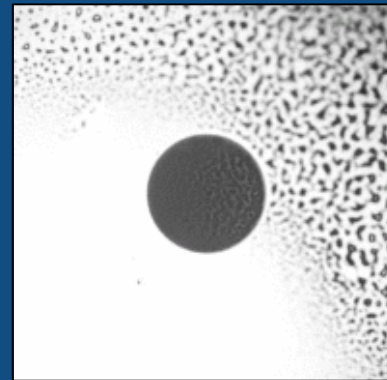
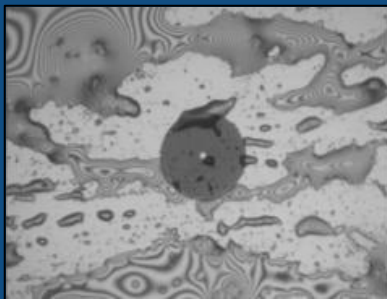
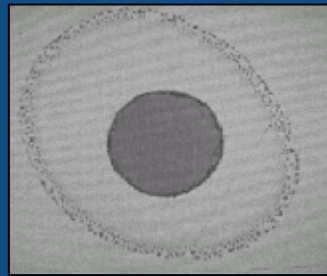
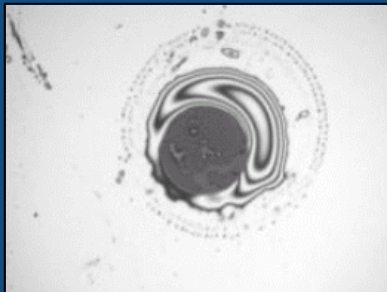


Core and cladding area fused and dented

Images courtesy of NTT

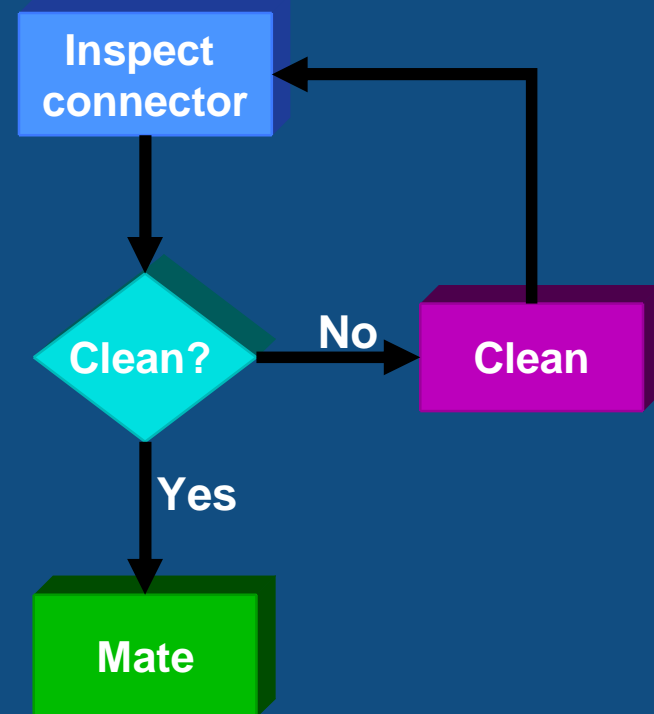
- Liquid residues have a different refractive indices than the fiber which create problems during physical contact.
- Residue contamination commonly interferes with back reflectance.

Examples of liquid and oil residues:

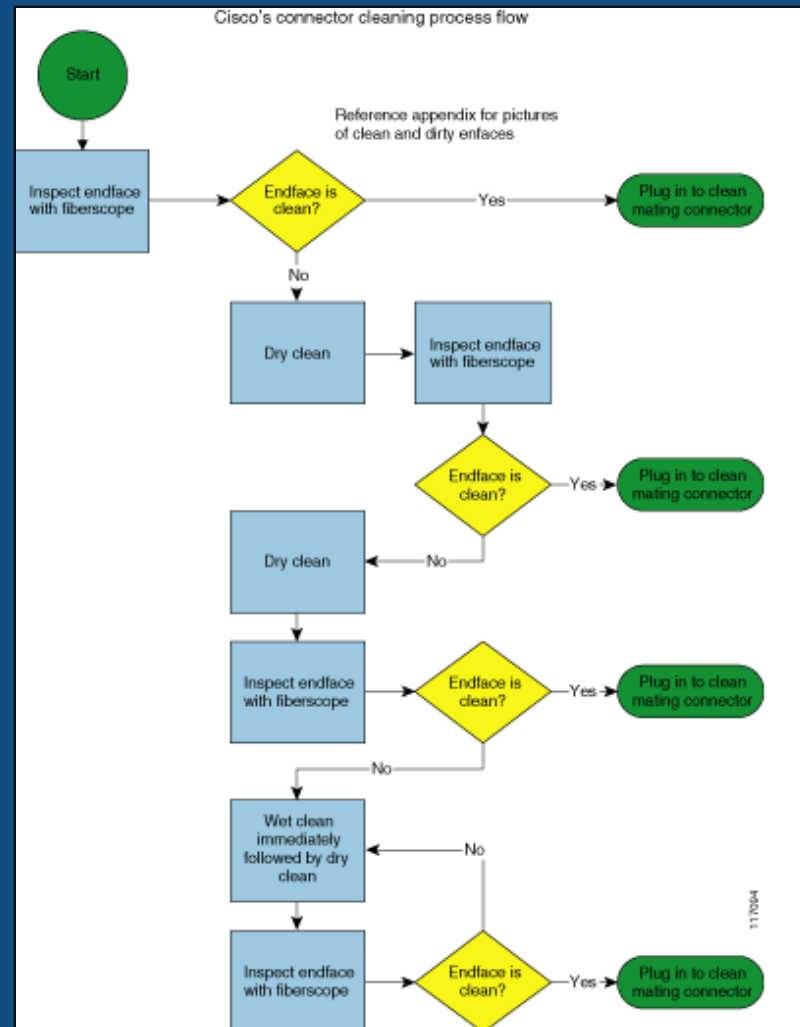


Example of
dried alcohol
residue

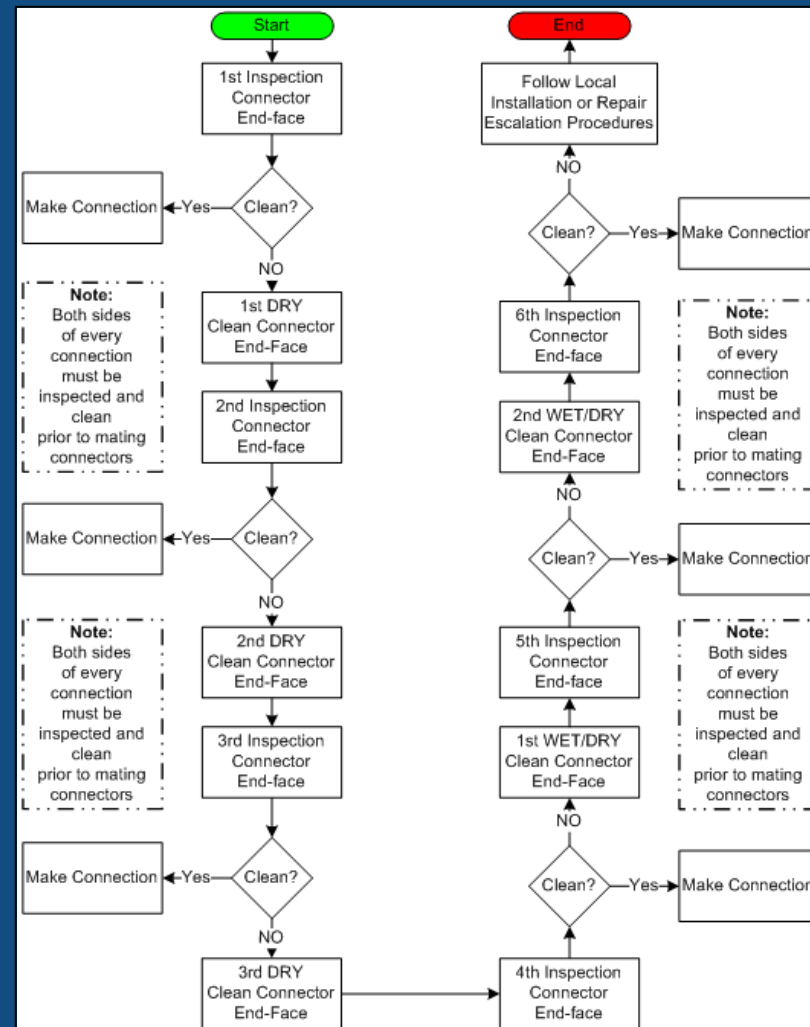
- Always inspect both connectors before mating.
- Mating dirty connectors will:
 - Cross contaminate both connectors
 - Hard contaminants will scratch and pit the ferrule end face
- Inspecting before mating will:
 - Prevent permanent damage to connectors
 - Reduced time trouble shooting times
 - Reduce material costs
 - Improve signal quality
- Make keeping fiber optic connectors clean a priority
 - Develop inspection and cleaning procedures
 - Train your team regularly on how to inspect and clean your connectors



- This workflow chart comes from Cisco Systems Document 51834 titled “Inspection and Cleaning Procedures for Fiber Optic Connections” which can be found in the public domain.
- Cisco Systems requires continual inspection of the ferrule end face after each cleaning.
- Cisco Systems advocates starting with dry cleaning. If the contamination is not removed after the second cleaning cycle, a wet-dry solution is called for.



- This workflow chart comes from AT&T Document ATT-TP-76461 titled “AT&T Fiber Optic Connector and Adapter Inspection and Cleaning Standards” which can be found in the public domain.
- AT&T’s procedures call for continual inspection and cleaning.
- AT&T procedures starts with dry cleaning connectors for the first three cleanings.



SOLVENT PROS:

- Are inexpensive and readily available in the market
- Good for helping reducing the potential for static charge
- Good for removing severe contamination

SOLVENT CONS:

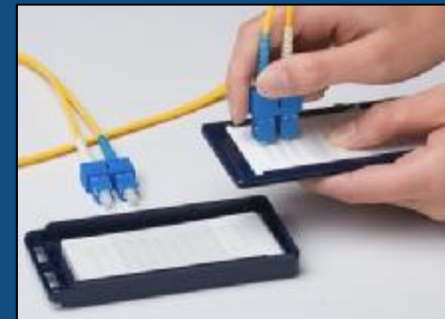
- Solvents that are not completely wiped off may leave residues behind
- Some solvents are highly flammable and require special handling and storage
- Some solvents use fluorocarbons which contribute to greenhouse gas emissions
- Alcohol based products are hygroscopic
- Accidental ingestion and prolonged exposure to most solvents will cause sickness and skin irritation at a minimum. Familiarize yourself with the MSDS before using any solvent.

Here are some suggested techniques for cleaning using cassettes, card cleaners and wipes:

- Always hold fiber tip lightly against the cleaning region.
- Do not press the ferrule too hard into the cleaning fabric or clean using the same surface more than once.
- For UPC polished ends, rotate the ferrule once through a quarter turn perpendicularly from the cleaning material.
- For APC (angled polished) ends, hold the cleaning area at the same 8° angle as the ferrule end face.
- Always inspect the ferrule after each cleaning using a ferrule scope. Many harmful particulates are not visible to the human eye.
- Do not try to reuse cleaning materials. The contamination that was taken off on the first usage will embed into the cleaning material.

There are number of effective options for cleaning patch cords:

- Wipes and solvents
 - Example: Isopropyl alcohol and tissues
 - Example: Perforated tissues in boxes or tubes and solvents
- Cassette cleaners
 - Example: OPTIPOP and CLETOP from NTT-AT
 - Example: Handi Mate™ from Seikoh Giken
- Automated cleaning systems
 - Example: CleanBlast by JDSU
- Mechanical cleaning tools
 - Example: IBC Brand Cleaners by US Conec
 - Example: Seikoh Giken Ferrule Mate
- Field cleaning cards
- Pipe cleaners



There are number of effective options for cleaning in bulkhead connections:

- Sticks and swabs
- In bulkhead mechanical cleaning tools
 - Example: IBC™ Brand Cleaners by US Conec
 - Example: Seikoh Giken Ferrule Mate™
 - Example; AEFOS AFC-3000
- Automated cleaning systems
 - Example: JDSU CleanBlast



JDSU CleanBlast bench



Seikoh Giken
Ferrule Mate™



US Conec IBC™ Brand Cleaners

Cleaning Method	Compressed Gas	Dry Wipes And Cassettes*	Solvents Only	Wipes and Cassettes With Solvents	Dry Swabs	Swabs With Solvents
Application						
Connector Endfaces (Patch Cords)	A	A	N	A	A	A
Connector Endfaces (In Adapters)	A	A	A	A	A	A
Alignment Sleeves (Adapters)	A	N	A	N	A	A
Dust Plugs And Caps	A	N	A	N	A	A

A = Applicable Method N = Non-applicable Method

Some materials may create a static charge on the ferrule endface which may attract contamination - IPC-8497-1 Table 7-1



IPC 8479-1 Dry Wipes

Use of fabric and/or paper wipes to provide combined mechanical action and absorbency to remove contamination.

ADVANTAGES:

Easy, convenient method

Woven or entangled fabric captures particulate debris and removes them from the surface being cleaned

DISADVANTAGES:

Only low-lint or lint-free wipes should be used

May create a static charge on the ferrule end face

Media must be protected from contamination until just prior to use

IPC 8479-1 Compressed Gas

Use of a fast moving gas to provide mechanical action to remove particulate contamination. Canned air, carbon dioxide, nitrogen, and air compressors are alternatives that may be used.

ADVANTAGES:

- Removes loose particles
- Speeds drying of solvents

DISADVANTAGES:

- Ineffective against oils including fingerprints
- Only moves; does not necessarily remove particles
- Must be filtered for moisture, oil, and particulates

IPC 8479-1 Solvents

Use of solvents provide a chemical action to clean fiber optic endfaces.

ADVANTAGES:

Provides more aggressive cleaning of contamination
Very effective against oils and dried-on contamination

DISADVANTAGES:

May leave a residue which can be difficult to remove
May only be effective when used with mechanical action such as wipes, swabs, or cassettes
Flammable liquids require DOT markings, are more costly to ship, and may require special storage
Open containers are easily contaminated

IPC 8479-1 Wipes and Solvents

Use of wipes and cassettes in addition to solvents provide a combination of chemical and mechanical actions.

ADVANTAGES:

Provides more aggressive cleaning of contamination
Very effective against oils and dried-on contamination

DISADVANTAGES:

May leave a residue which can be difficult to remove
Binders and glues used in manufacture of some wipes and swabs may be released by the solvent and deposited on the connector end face

IPC 8479-1 Dry Swabs

Use of dry swabs may be beneficial since they are designed to clean connector end faces while installed in mating adapters and the alignment sleeves themselves.

ADVANTAGES:

- Allows the cleaning of ferrule end faces while installed in mating adapters

- Allow cleaning of some military-style connectors without requiring disassembly of the connectors

DISADVANTAGES:

- More costly than other methods

- Mechanical action alone may not remove all contaminants due to the physical constraints of the adapter limiting wiping ability

- Different size swabs may be required to clean different style connectors

IPC 8479-1 Dry Swabs with Solvents

Combining swabs with the appropriate solvent provides a combination of chemical and mechanical actions.

ADVANTAGES:

Provides more aggressive cleaning of contaminants
Very effective against oils and dried-on contamination

DISADVANTAGES:

May leave a residue which can be difficult to remove
Binders and glues used in manufacture of some swabs may be released by the solvent and deposited on the connector end face
Different size swabs may be required to clean different style connectors
Only very fast drying solvents should be used



When trying to decide which cleaning solution will work best for your application, ask yourself these question:

- What connector types will need to be cleaned?
- What type of contaminates will my technicians encounter?
- Where are the connectors physically located in the network?
- How many connector ends will need to be cleaned for this project?
- What type of environment have the connectors been exposed to?
- What is the skill level of my technicians for cleaning fiber connectors?
- What type of environment will my technicians be cleaning in?
- Does the equipment or cable system manufacturer have cleaning requirements that must be followed for maintaining the warranty?

Final Thoughts:

**A connector does not always have to be pristine.
Some flaws are acceptable.**

Not all cleaning products are the same.

Never assume that a new cable assembly is clean.

This concludes my presentation.

Thank you for your time and support of BICSI.

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