



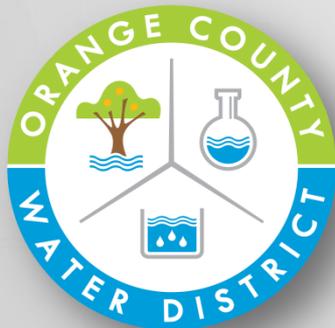
IUVA Americas Conference

February 26-28, 2018

Redondo Beach, California, USA

Investigation of Cause of Quartz Sleeve Hazing In UV/AOP System for Potable Reuse

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and
Ken Ishida



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Acknowledgements - Water Production Staff -





GWRS Advanced Water Purification Facility

**Microfiltration
(MF)**



**OCSD
Secondary
Effluent**

**Backwash
OCSD Plant 1**

**Reverse
Osmosis
(RO)**



**Brine
OCSD Outfall**

**Ultraviolet Light
with H₂O₂
(UV/AOP)**



Barrier
**Recharge
Basins**



Ultraviolet/Advanced Oxidation Process (UV/AOP)



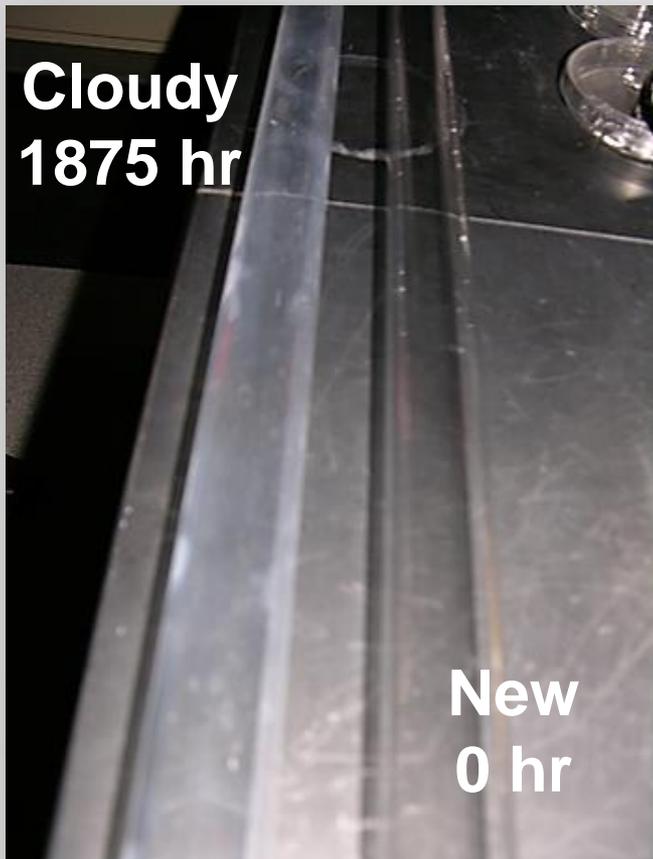
- 100 MGD Trojan UVPhox System
 - 13 trains
- Low pressure – high output lamp system
 - 432 lamps per train
 - 257 watts per lamp, end-of-lamp-life of 12,000 hours
 - Each lamp is housed in a quartz sleeve
- Destroys trace organics
- Uses hydrogen peroxide to create an Advanced Oxidation Process



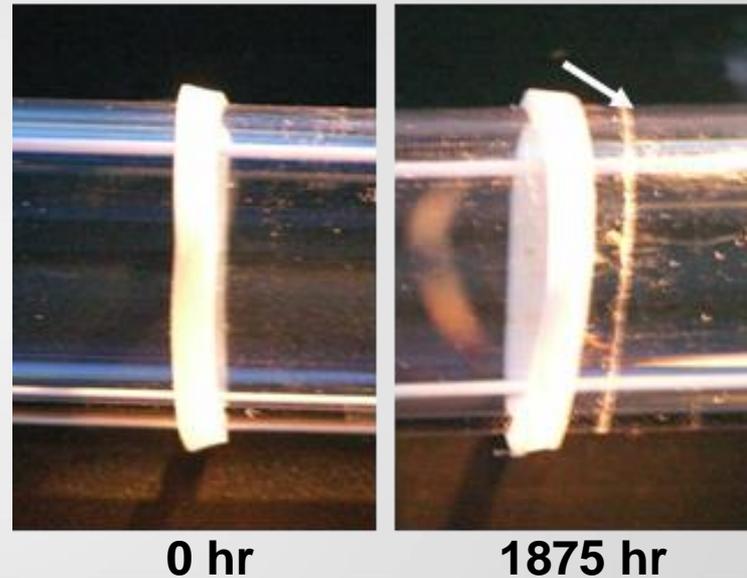


Hazing and Moisture of Quartz Sleeves and UV Lamps

Quartz Sleeves



UV Lamps



- Study on localized spots showed reduction in UVT varied between **3%, 12% and 20%**

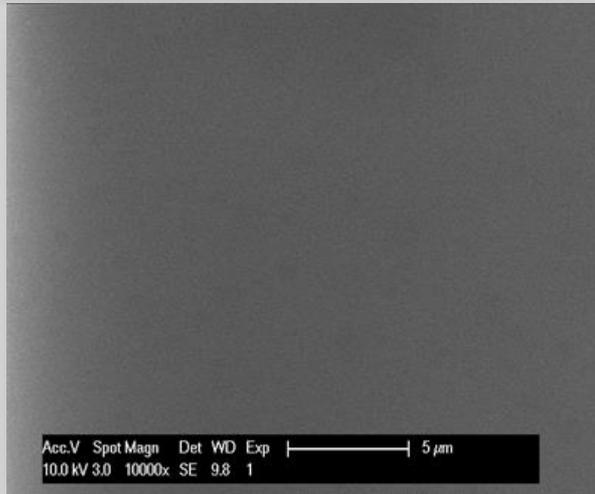


Scanning Electron Microscopy and Energy-Dispersive X-ray Spectroscopy (SEM/EDS)

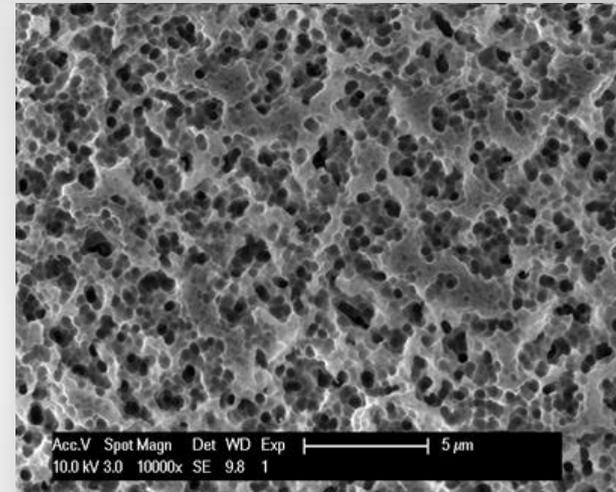
- To ascertain the nature of the UV hazing, analysis was performed on:
 - New and used (hazed) quartz sleeves
 - Teflon O-rings removed from new and old lamps



Quartz Sleeve SEM/EDS Results



Virgin Quartz Sleeve



Cloudy Quartz Sleeve

<u>Element</u>	<u>Atom %</u>
C	4
O	57
Si	39

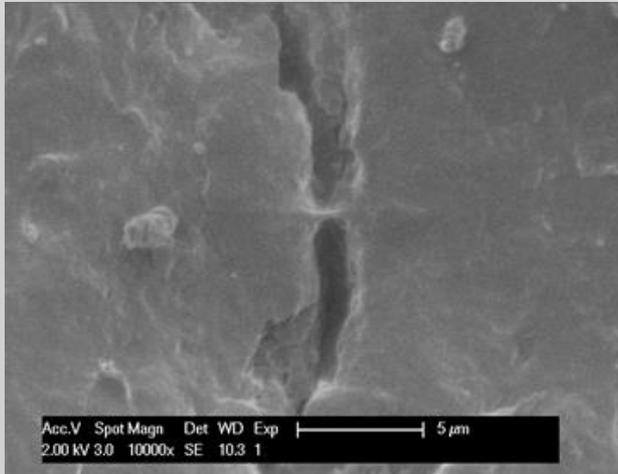
EDS Results

<u>Element</u>	<u>Atom %</u>
C	5
O	60
Si	35

- Cloudy quartz surface had egg shell appearance
- Virgin quartz was very smooth with no discernible topographical features
- Only silicon and oxygen on both virgin and cloudy quartz sleeves were detected

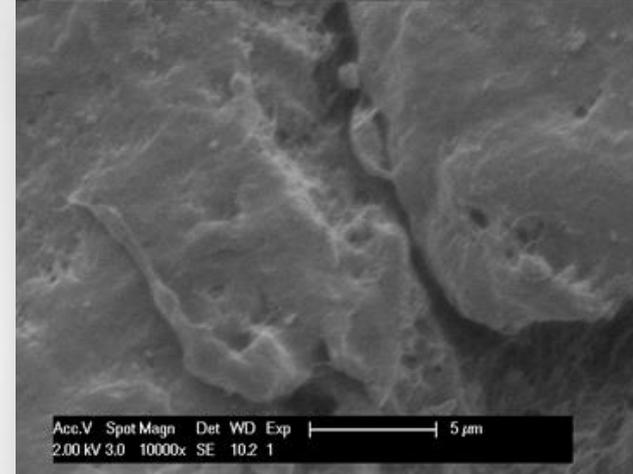


Teflon O-ring SEM/EDS



Virgin Teflon O-ring

<u>Element</u>	<u>Atom %</u>
C	63
F	36



Cloudy Teflon O-ring

EDS Results		<u>Element</u>	<u>Atom %</u>
		C	33
		O	8
		F	59

EDS shows oxygen incorporated on the surface of UV-exposed Teflon, presumably due to oxidation of the polymer



Teflon O-ring

- Studies have shown that thermal degradation of Teflon leads to the slow breakdown of the fluorinated polymer and the generation of a litany of toxic fumes including TFE (tetrafluoroethylene), HFP (hexafluoropropene), OFCB (octafluorocyclobutane), PFIB (perfluoroisobutane), carbonyl fluoride, CF_4 (carbon tetrafluoride), TFA (trifluoroacetic acid), trifluoroacetic acid fluoride, perfluorobutane, SiF_4 (silicon tetrafluoride), **HF (hydrofluoric acid)**, and particulate matter
- HF is known to etch glass
- <http://fluoridealert.org/wp-content/pesticides/teflon.decomposition.prod.htm>
- http://www.quartzpage.de/gen_chem.html



UV Quartz Sleeve Hazing Hypothesis

Hypothesis

Since moisture seeps into the sleeve during operation, one possibility is that a layer of water condenses on the cooler interior walls of the quartz sleeve, and the HF gas produced from Teflon oxidation is rapidly absorbed into the aqueous condensate etching the quartz surface.

Solution

Keeping the inside of the sleeves dry should keep the HF from the quartz surface, eliminating etching.



Monitoring Program

- **Control sleeves and lamps** – new sleeves and lamps installed according to standard operational protocol (SOP)
- **Dry sleeves and lamps** – sleeves were purged with nitrogen gas before sealing to test if maintaining a dry environment prevents etching
- **Wet sleeves and lamps** – 1 mL of UV product water (UVP) placed in the sleeve with the lamp to test if the presence of moisture results in the formation of a corrosive environment and hazing (etching)



Control - SOP

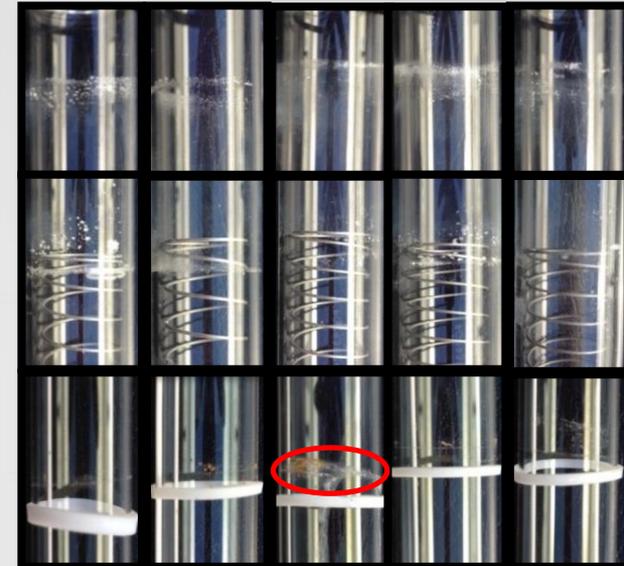
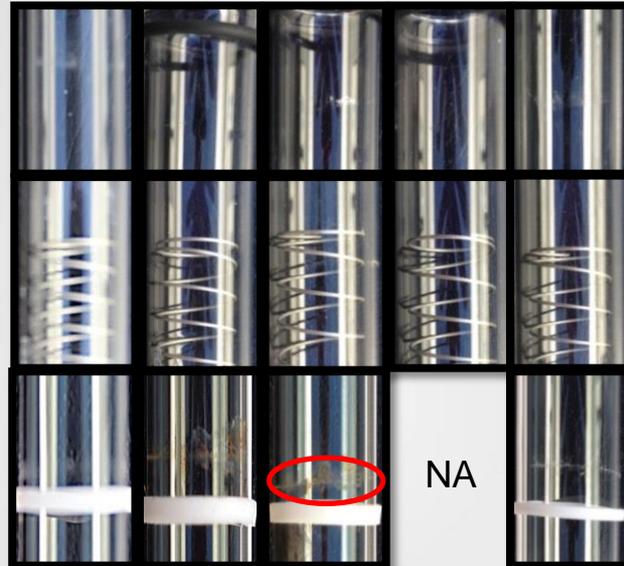
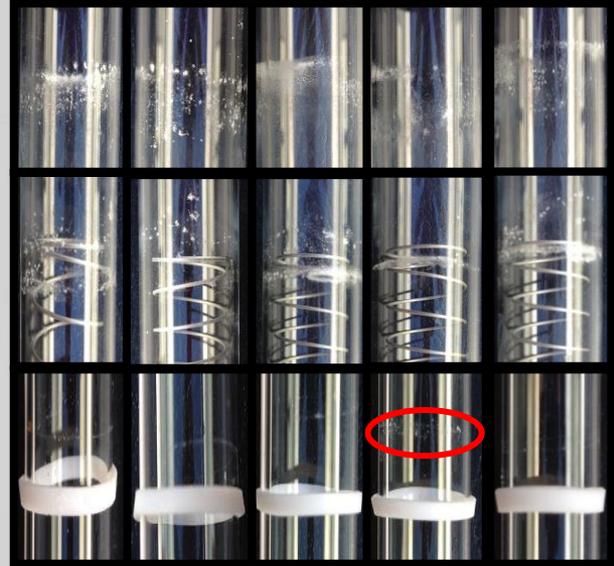
Wet

Dry (Nitrogen Gas)

35 40 47 67 69

34 41 46 66 71

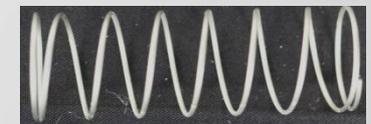
36 43 48 68 70



New Quartz Sleeve, 0 hr



New UV Lamp
0 hr

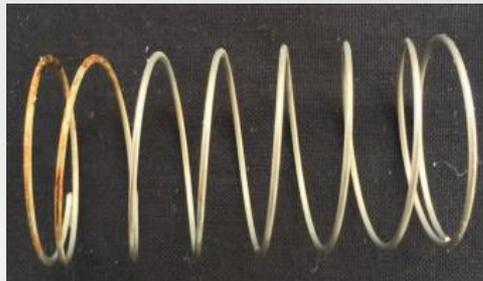
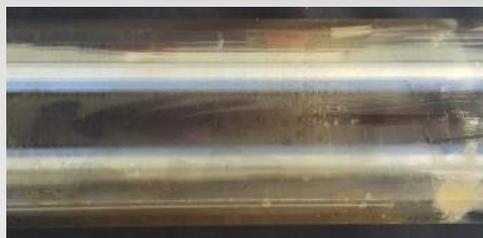
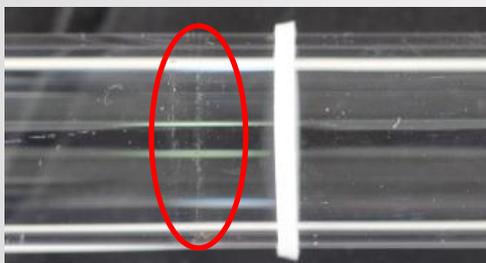
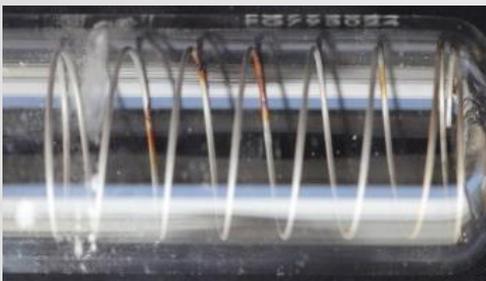
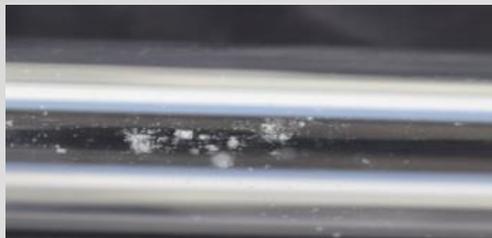


New SS Spring
0 hr

UV quartz sleeves and lamps after 1624 hours of UV exposure



**Control
SOP**



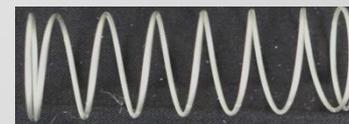
**Wet
1 mL UVP**



New Quartz Sleeve, 0 hr

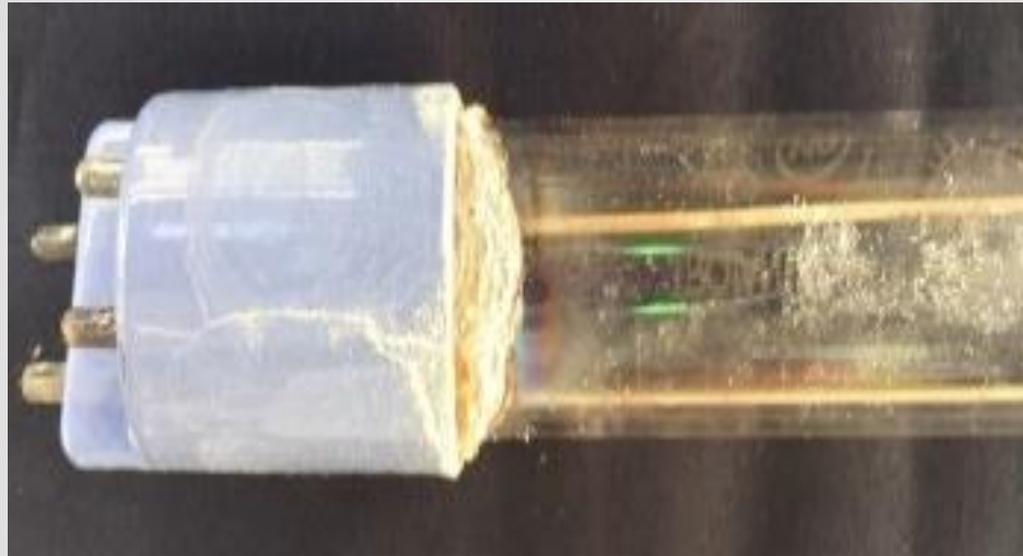


New UV Lamp
0 hr



New SS Spring
0 hr

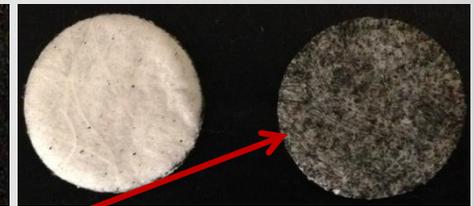
UV quartz sleeves and lamps after 7544 hr of UV exposure



UV Lamp after 7544 hr of UV exposure in wet environment

Addition of HF Absorbent

- Thermal degradation of Teflon O-rings leads to HF generation resulting in quartz sleeve etching.
- Addition of HF neutralizer/absorbent was added to prevent the build-up of acid inside the quartz sleeve.

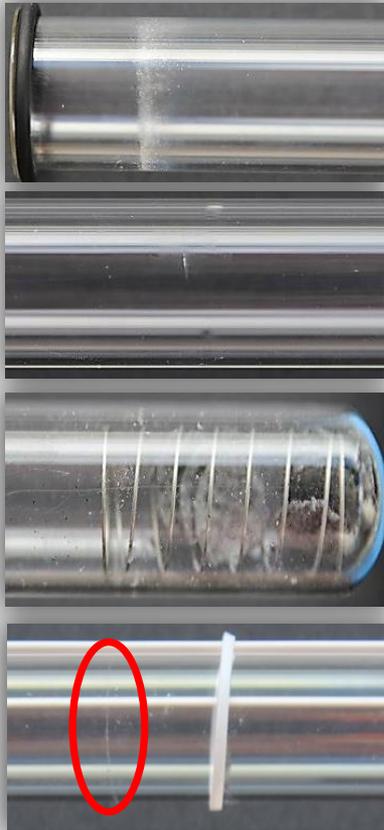


Absorbent





HF Absorbent – Results



1781 hr



5447 hr

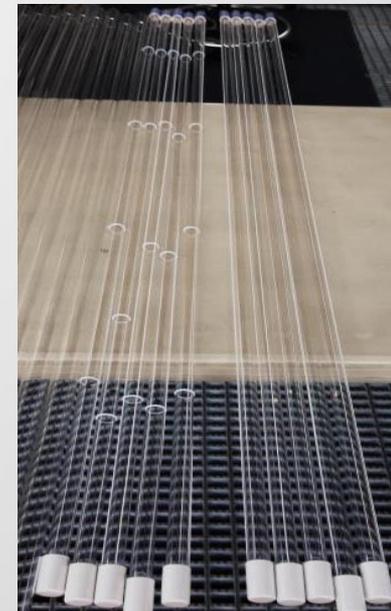
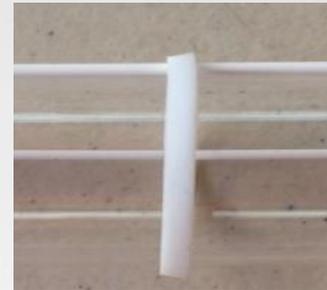
- HF absorbent was effective in preventing significant hazing
- Hazing was only found near the sleeve openings and ends with stainless steel springs
- Lamp etching was minimal at the Teflon O-ring locations
- HF absorbent broke down after long UV exposure





Removing the Source of HF – Teflon O-rings

- Removed Teflon O-rings prior to lamp installation
- Lamps installed according to SOP





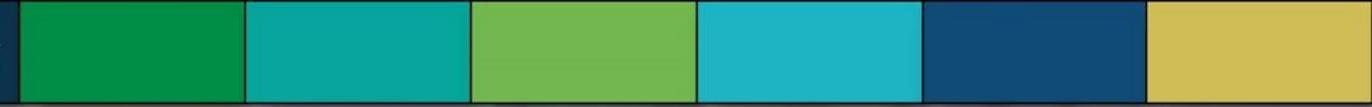
	37	38	45	57	72
UV Lamp					
Quartz Sleeve Open End	NA				NA
Quartz Sleeve Middle					
Quartz Sleeve Closed End					
Stainless Steel Spring					

After 5447 hr of UV exposure; no observable etching on either sleeves or lamps



Conclusions

- During UV exposure and in the presence of moisture, the production of hydrofluoric acid (HF) from Teflon O-ring oxidation appears to cause etching of the quartz sleeve surface. A layer of condensed water forms on the cooler interior of the UV sleeves, and the HF gas is solubilized into this layer causing the etching of the quartz surface
- Increasing the moisture volume in the quartz sleeve appears to dilute the HF resulting in reduced quartz sleeve etching
- Etching of the UV lamps was only observed in locations where the Teflon O-rings came in contact with the lamp surface
- The use of an HF absorbent can be an effective method in preventing quartz sleeve etching. Due to the short life of the HF absorbent under UV conditions, this method is not practical
- Removing the Teflon O-rings from the UV lamp surface is an effective method to prevent both quartz sleeve and lamp etching. HF cannot be generated when the fluorinated polymer, Teflon, is not present.



Thank You!

Questions?