

National Aeronautics and  
Space Administration



**Stennis Space Center**

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# **A-1 LOX & LH Runline Contamination**

**RTG Meeting – December 2-3, 2014**  
**Nugent, Jacks and Hebert**

# A-1 LOX & LH Runline Contamination



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# A-1 LOX & LH Runline Contamination

## Background

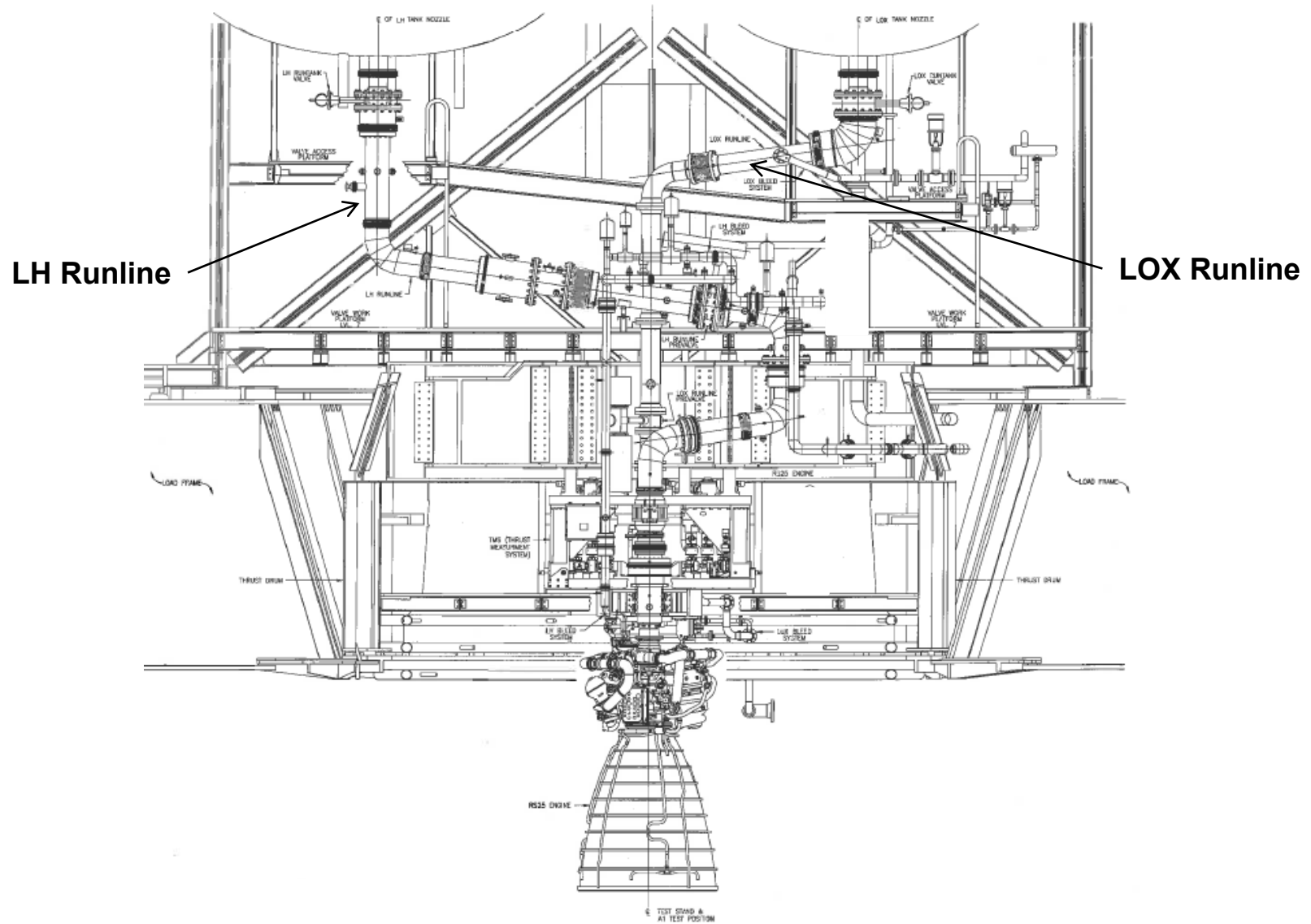


- **An engine test program is to be executed on SSC's A-1 test stand which resulted in the need to design and fabricate the STE (special test equipment) piping between the facility connections and engine interfaces**
- **A new piping analysis and design was provided by an experienced onsite contractor**
  - Materials specified in the construction package in the usual format
  - The design required new piping and fittings to be procured
- **New piping procurements handled by onsite contractor using industry standard specifications and NASA SSC piping standards**
- **Upon receipt of the new raw piping and fittings, quality personnel performed a standard inspection to verify all items met the procurement specifications**
- **Fabrication and installation of the new piping was performed by onsite contractors that are familiar with piping of this nature**
- **Piping was cleaned and sampled in-house per NASA standards**

# A-1 LOX & LH Runline Contamination Background



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# A-1 LOX & LH Runline Contamination

## Background



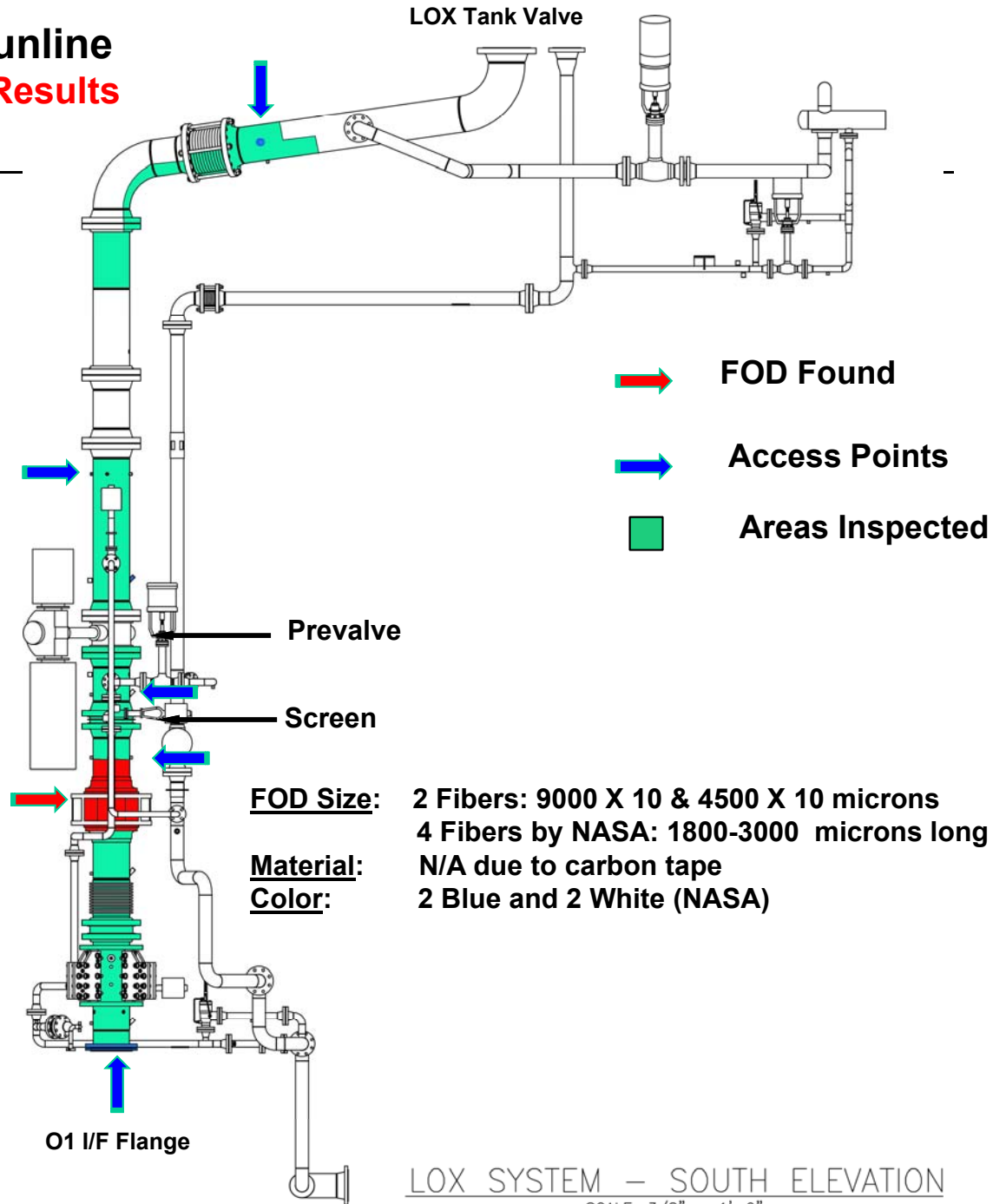
- During LOX Lower Runline inspections on 6/19/14, numerous fibers were observed between the run line screen and O1 interface flange.
- Subsequent inspections of the LH Upper Runline on 6/26/14 revealed fibers between the LH Run Tank isolation valve and the runline screen (including the runline screen)
- All involved runlines/screens were installed new.
- Fiber sizes exceed cleanliness requirements as identified on the SSC piping schematics:
  - LOX: Drawings PSK-A1-2001-FAC & PSK-A1-2001-RS25
    - \*RPTSTD-8070-0001 Level 750A with a maximum particle size of 750 microns allowed
  - LH: Drawings PSK-A1-1001-FAC & PSK-A1-1001-RS25
    - RPTSTD-8070-0001 Level 400 with a maximum particle size of 400 microns allowed
  - Samples have indicated fibers up to 9000 microns long
    - RPTSTD-8070-0001 defines fibers as particulate

\*RPTSTD-8070-0001 “Surface Cleanliness Standard of Fluid Systems for Rocket Engine Test Facilities of the NASA Rocket Propulsion Test Program”

# A1 LOX Runline Inspection Results



AR Borescope Photos



# A-1 LOX Runline

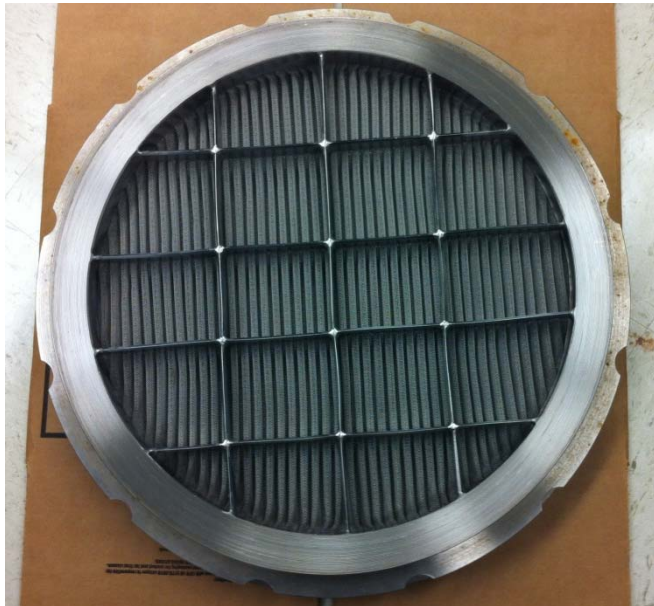
## 12" Screen



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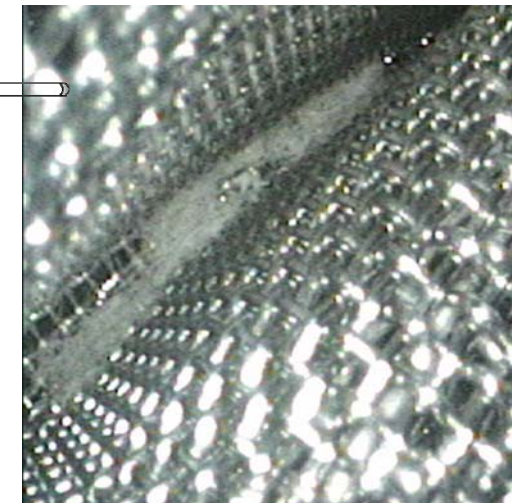
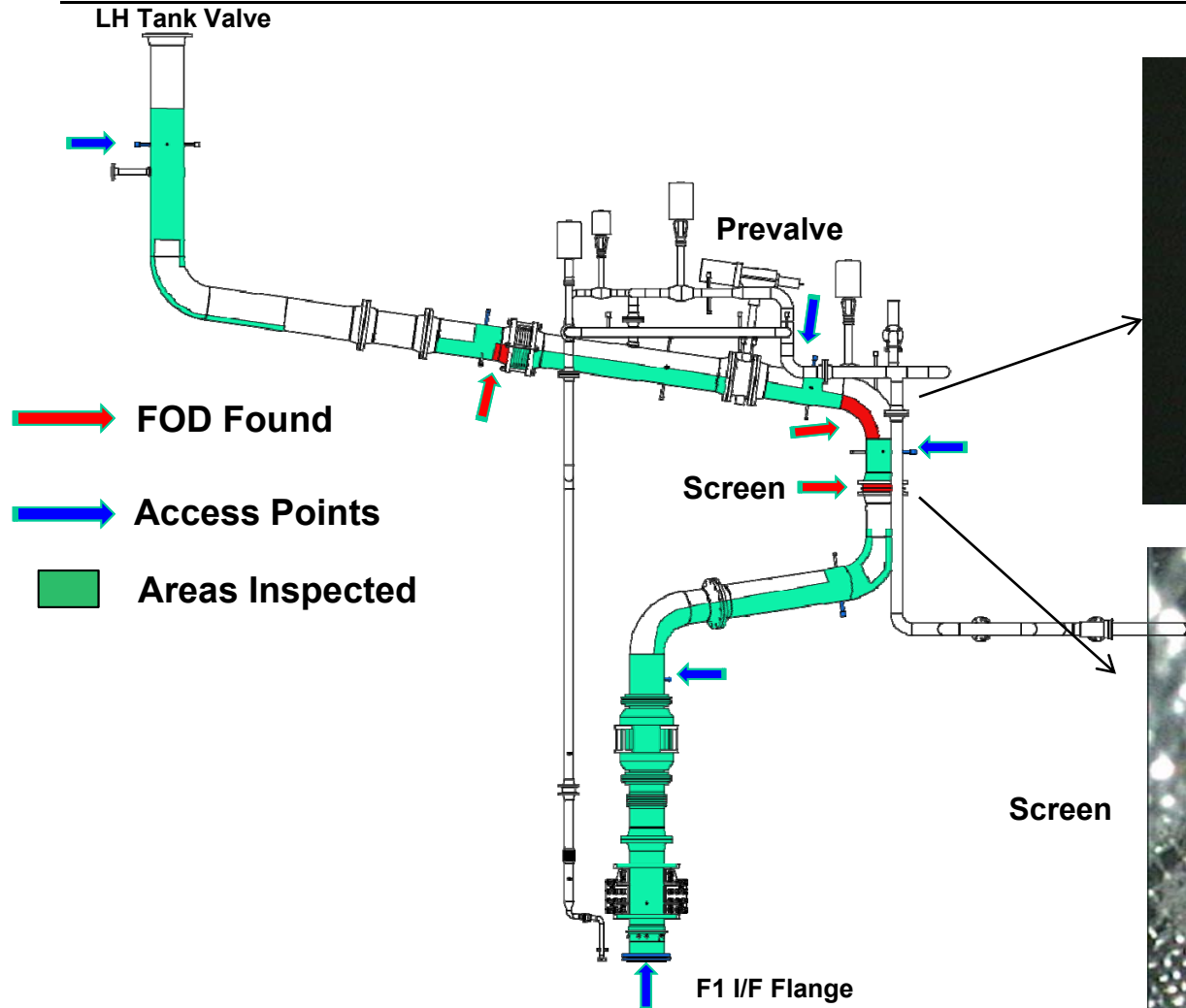
- **Original Runline screen removed and replaced with spare screen. Original Screen inspected:**
  - **Few cotton fibers located on inlet/outlet side.**
  - **Strong fluorescence under Black Light**
  - **Fibers appear to be resting on inlet surface and migrating towards outlet**
  - **304 SST particle with entrapped cotton fibers**
- **Screen manufacturer (Erbe) contacted**
  - **No cotton wipes used for processing or shipping**



# A1 LH Runline Inspection Results



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Borescope Photos

**FOD Size:** 2 Fibers removed: 1200X60 microns  
1 Fiber removed by NASA millipore: 1800 microns  
**Material:** Cotton (NASA millipore Fiber)  
**Color:** Blue and White



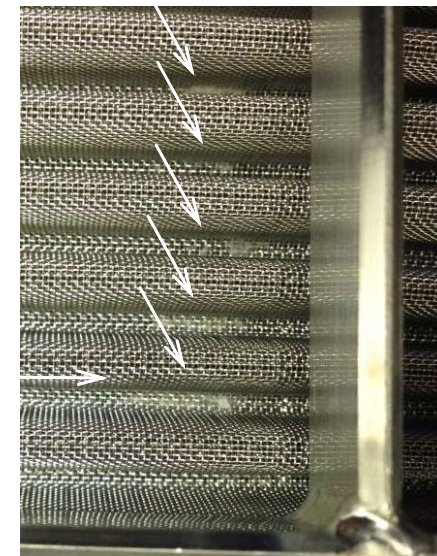
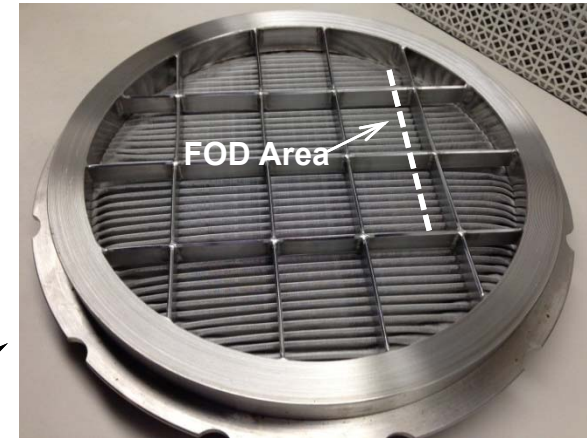
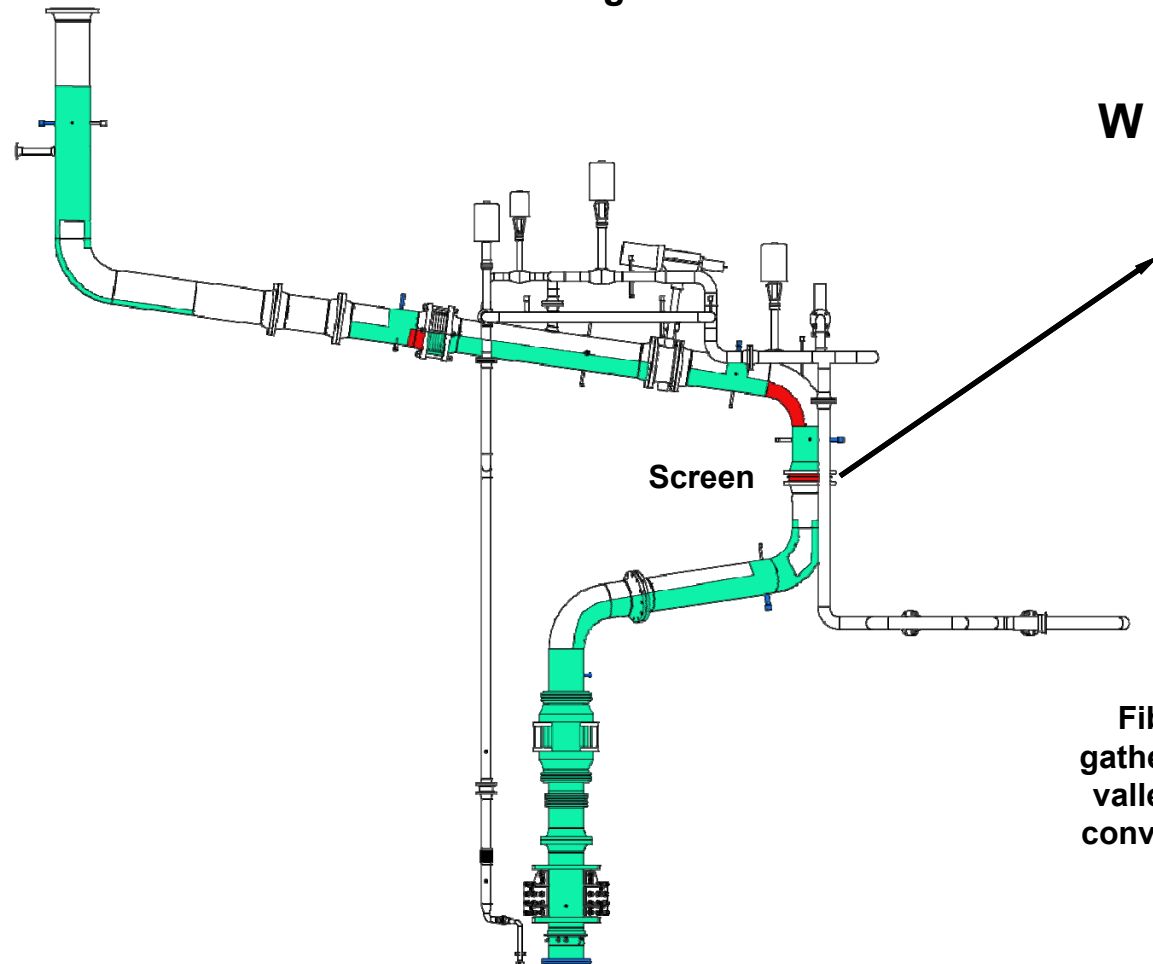
# A-1 LH Runline

## 12" Screen



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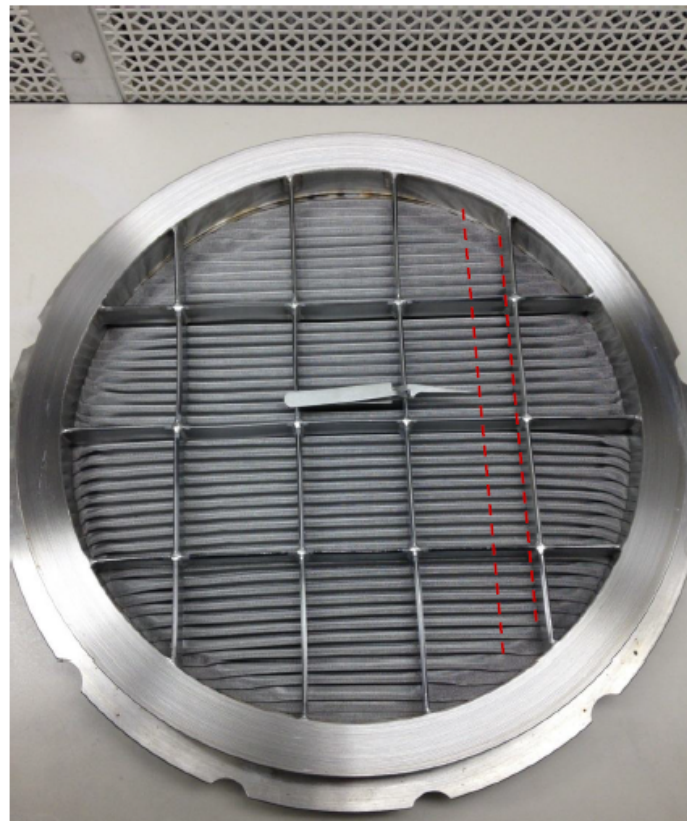
- Original screen remove and replaced with clean spare screen
- Numerous visible, cotton fibers located on original screen
- Fibers located on "east" edge of screen as installed



# A-1 LH Runline 12" Screen



## A1/TS LH 12" Original Screen Inlet Side FOD (Non-Metallic Fibers) Delivered to GMSL 7/15/2014

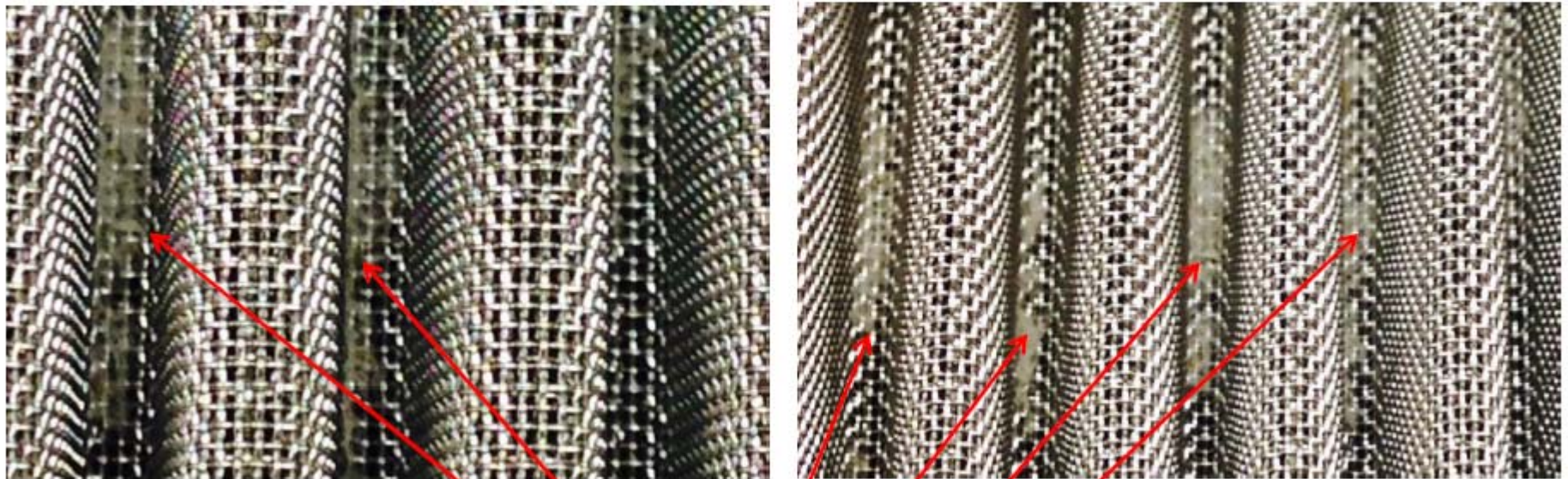


The FOD fibers are mostly confined within the pleated valley regions as highlighted by the red dash lines.

Based on the Two Acid ( $H_2SO_4$  &  $HCl$ ) Tests, the Solubility and Color Changes are Consistent with Cellulose (e.g., cotton) Fibers.

# A1/TS LH2 Original Frantz Screen

Inlet Side



FOD (Fibers) in the Screen Valleys

# A-1 LH Runline 12" Screen



## A1/TS LH 12" Original Screen Inlet Side

Delivered to GMSL 7/15/2014



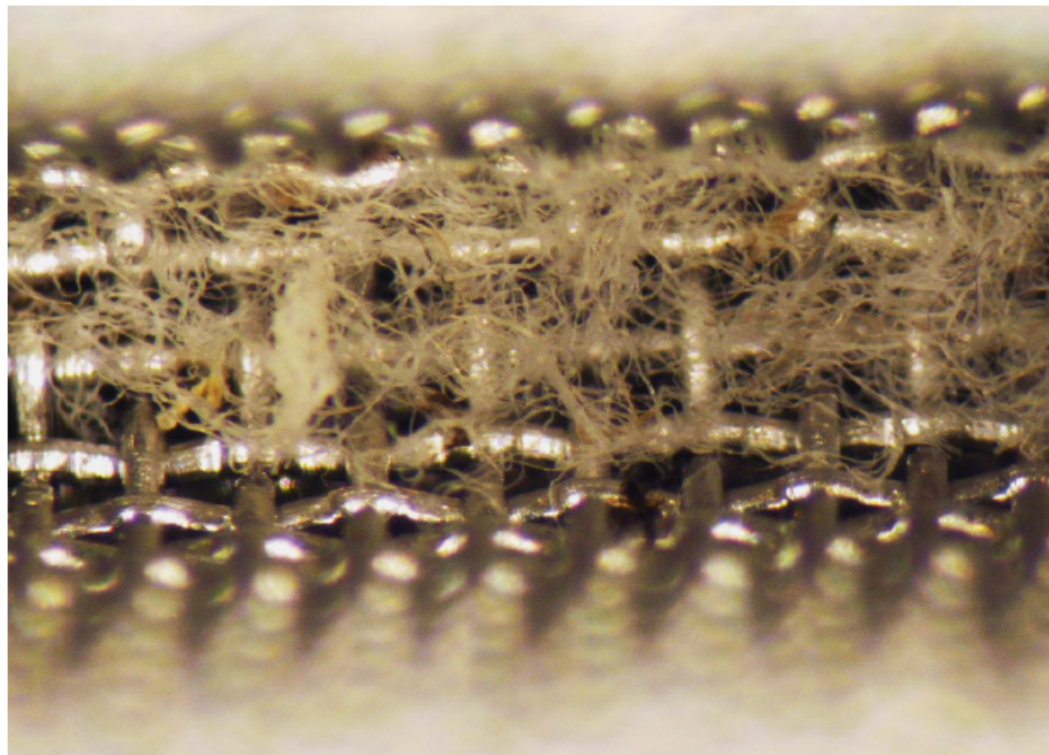
UV Illuminated Image Shows the Accumulation of  
Fibers in the Pleated Valleys

# A-1 LH Runline 12" Screen



## A1/TS LH 12" Original Screen Inlet Side

Delivered to GMSL 7/15/2014



Optical Microscope Image of the Inlet Side - The majority of the fibers are  $> 2000\mu$  and are confined to the screen valleys . The non metallic fibers are flexible ( diameter is  $< 50\mu$ ; consequently, several fibers have traveled below the surface.

# A-1 LH Runline 12" Screen



## A1/TS 12" LH Original Screen Outlet Side

Delivered to SSC/ GMSL 7/15/2014



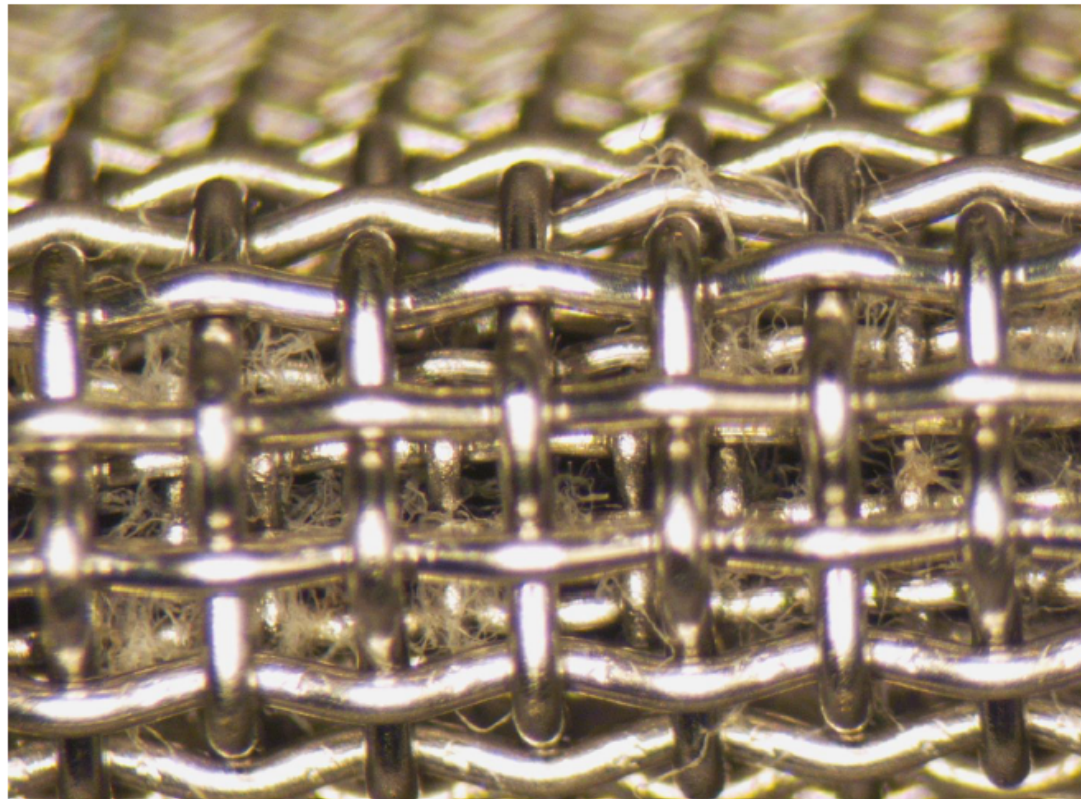
UV Illuminated Image Shows the Fibers are  
Confined to the Crest Areas

# A-1 LH Runline 12" Screen



## A1/TS LH 12" Original Screen Outlet Side

Delivered to GMSL 7/15/2014



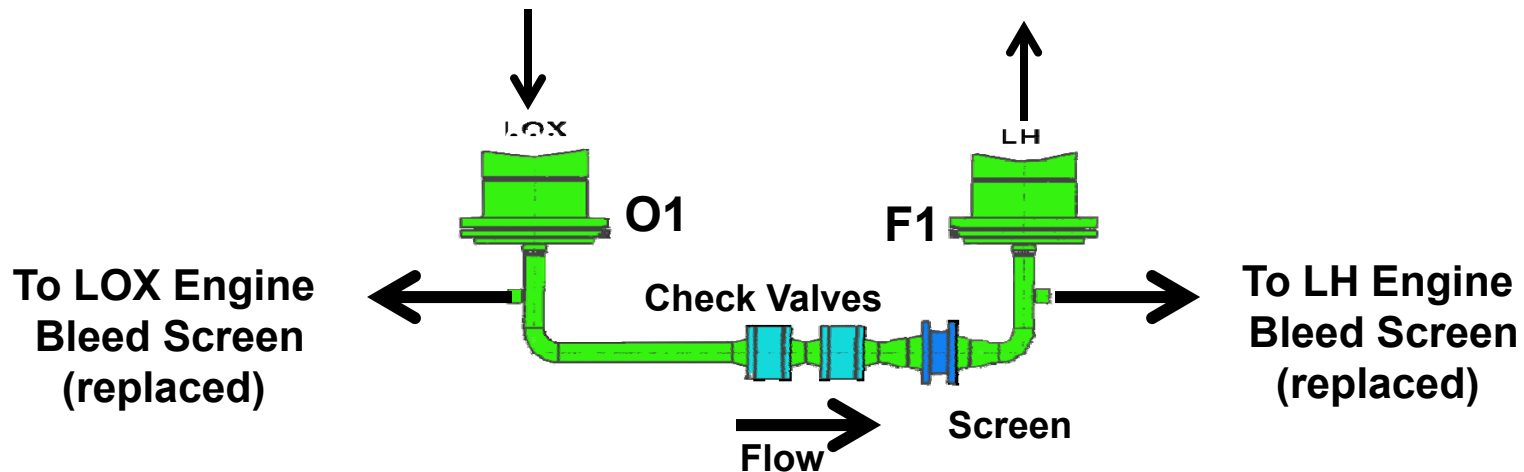
Optical Microscope Image of the Screen Crest on the Outlet Side - The fibers are confined between the two pleated screens. The fibers are more concentrated on the inlet side (in the screen valleys). Some of the fibers have migrated through both filter screens and have traveled to the surface.

# A-1 LOX & LH Runline Contamination

## LN Coldshock Crossover Spool



- **LN Coldshock**
  - Major components utilized during coldshock removed and inspected:
    - Two (2) 3" crossover check valves: one white fiber, one blue fiber, all cotton,
    - 3" crossover screen: one blue cotton fiber
    - 3" LOX Engine bleed screen: one cotton fiber
    - 3" LH Engine bleed screen: Two (2) fibers, too small to characterize
  - Engine bleed screens replaced with cleaned hardware



**3" LN Coldshock Crossover Spool**



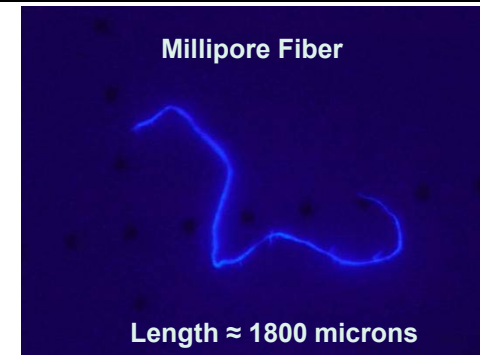
# A-1 LOX & LH Runline Contamination

## Fibers Found in Runlines: Summary

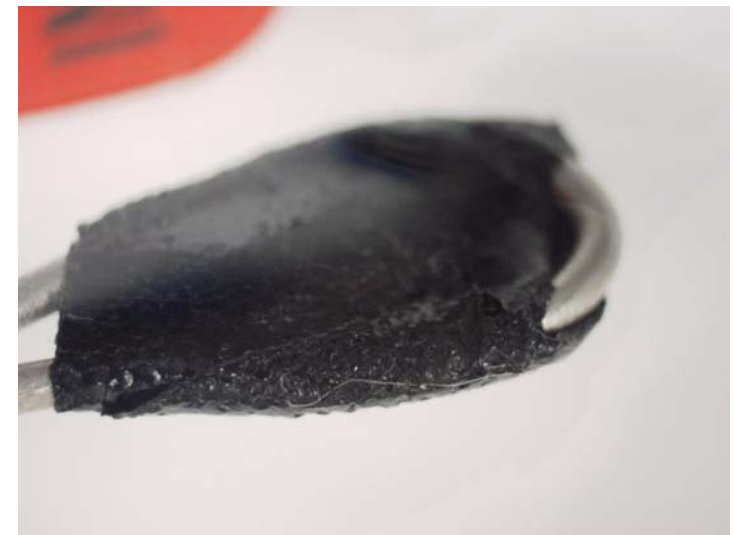
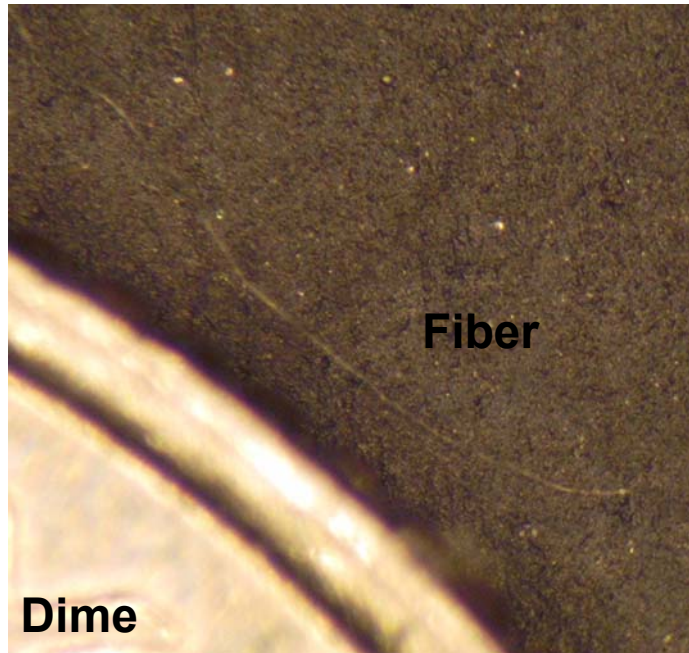


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- **Fibers from Runline/Screens**
  - **White and Blue**
  - **Up to 9000 microns**
  - **Cotton**
  - **Highly Fluorescent**



The fiber fluoresces when examined by blacklight and has mechanically worked features (i.e. frayed and pulled areas). Under visible light, the thinner sections appear translucent while the thicker sections appear milky white. Material properties are consistent with a cellulose based fiber (e.g. cotton).

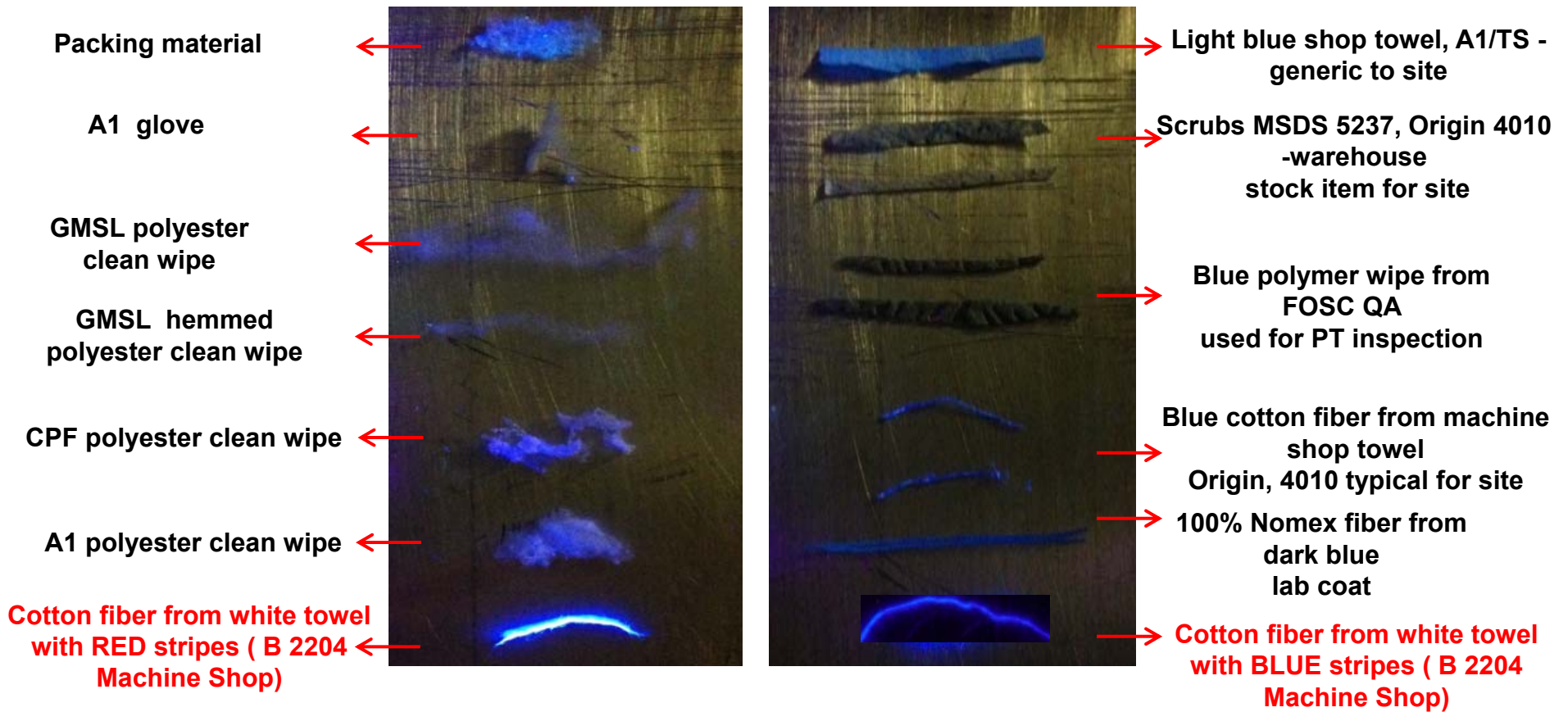


# A-1 LOX & LH Runline Contamination

## Fluorescence Intensity of On Site Fibers from UV Illumination



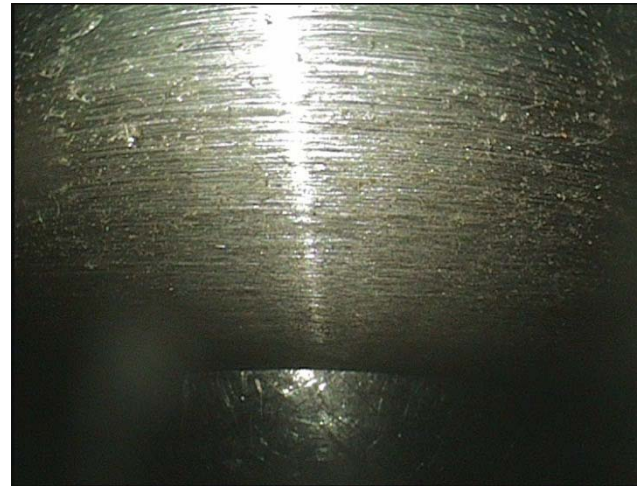
- Numerous on site fabrics/wipes were tested to compare fluorescence intensity to runline FOD
  - Two (2) wipes displayed similar intensity
    - White rag with red stripe (Cotton)
    - White rag with blue stripes (Cotton)
- These two (2) wipes selected for further testing



# A1 Runline Contamination Investigation Utilizing Leftover Piping Spools



**Leftover LOX Spool**



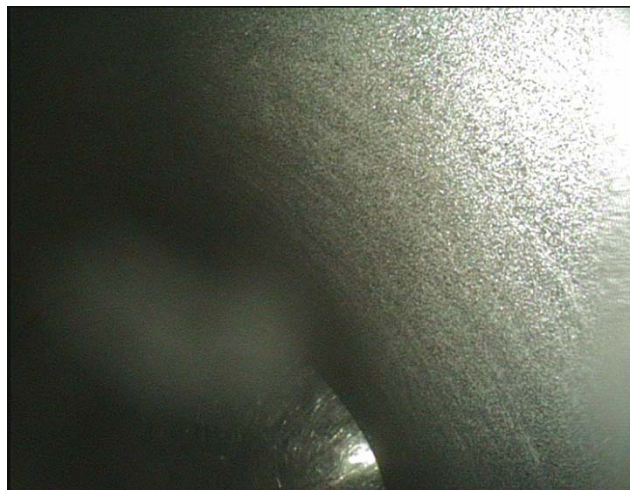
**Leftover LOX Spool Borescope**



**A1 LOX Runline**



**Leftover LH Spool**



**Leftover LH Spool Borescope**



**A1 LH Runline**

# A-1 LOX Runline

## Leftover Piping Investigation: LOX Short Spool



- Two (2) remnants piping spools from same A-1 LOX piping lot# located in outside storage area and used as test specimens:
  - Short LOX Spool (14'') and Long LOX Spool (6')
- Short spool:
  - Borescope Inspected: ~5-10 Cotton Fibers initially
    - Potentially from previous handling
  - Typical dirt and debris from being in storage yard



Short LOX Spool

# A-1 LOX Runline

## Leftover Piping Investigation: LOX Long Spool



- **Long Spool relocated from storage area to CPF**
  - Initial inspections: No fibers indicated
- **Long Spool wiped with white cotton rag w/red stripe**
  - Numerous fibers remained in spool
  - Fibers consistent with FOD from runline

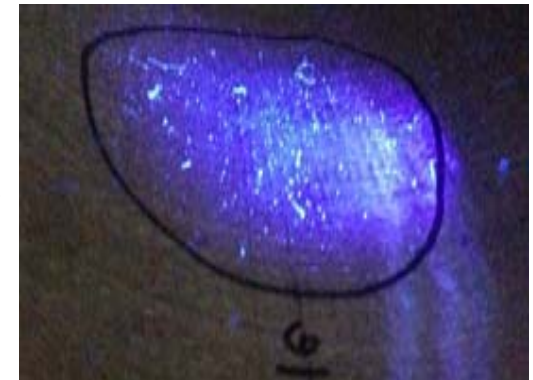


LOX Long Spool

Black Light



Prior to Wipe



Post Wipe

Borescope

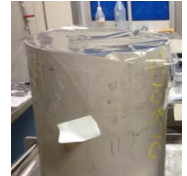


# A-1 LH Runline

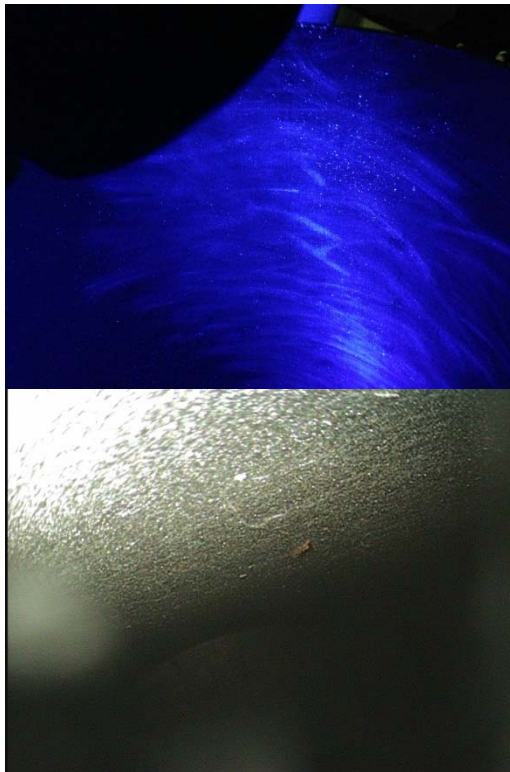
## Leftover Piping Investigation: LH Spool



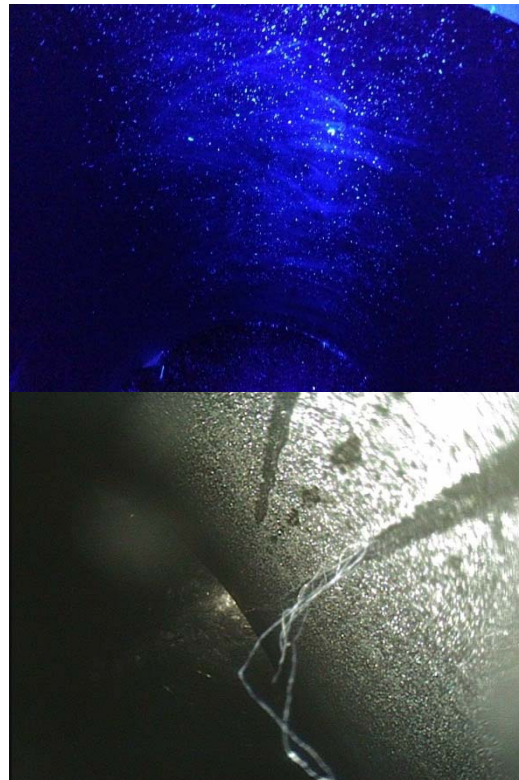
- One (1) remnant piping spool from same Lot# located in outside storage area and used as test specimen:
  - No fibers initially. Spool cleaned at CPF.
  - Spool then wiped with cotton wipe (white w/blue)
    - When using aggressive wiping, no long fibers indicated. Numerous smaller debris
    - When using normal wiping, fibers indicated on scoured/raised areas.
  - Sent to Component Processing Facility (CPF) for cleaning
    - Reinspected: All loose particulate removed. Fiber remained on scoured/raised area



Aggressive Wiping



Normal Wiping



Post Cleaning



# Procurement of Pipe



- SSC does not specify a surface finish or minimum roughness value when procuring pipe
- References ASTM A312
- Picture below shows what was specified for the procurement of the A1 LOX pipe in question

	<u>Quality Codes (VPR)</u>	<u>Qty Rec to Date</u>	<u>Qty Ordered</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Ext. Price</u>
Item: 3	1:04 2: 3: 4:	40	40	FT	\$591.62	\$23,664.80
Part No:		MSDS#	0	Equipment? N	AP Flag? N	RCDI
Desc: PIPE; 12" SCH 40 ( WALL THICKNESS .406 IN) SEAMLESS, GR TP					QTY Rec:	40
304/304L DUAL RATED, ASTM A312					Value:	\$23,664.80
		Date Rec:	10-MAY-2013			

# Standards and Specifications

## ASME & ASTM



- **ASME 31.3 - ASME Code for Process Piping**
  - Does not specify minimum roughness value or surface finish for pipe
- **ASTM A312 -Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes**
  - 6.1.7 “The pipe shall be free of scale and containing exogenous iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser is permitted to require that a passivating treatment be applied to the finished pipe.”
  - 14.1 “The finished pipes shall be reasonably straight and shall have a workmanlike finish. Removal of imperfections by grinding is permitted, provided the wall thicknesses are not decreased to less than that permitted in Section 9 of Specification A999/A999M.



# Standards and Specifications

**ASTM**



- **ASTM A999 - Specification for General Requirements for Alloy and Stainless Steel Pipe**
- **Section 28- Government Procurement**
  - 28.8 Pipe shall be free from heavy oxide or scale. The internal surface of hot finished ferritic steel pipe shall be pickled or blast cleaned to a free of scale condition equivalent to the CSa2 visual standard in SSPC-SP6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.
  - 28.13 **Pipe shall be uniform in quality and condition and have a finish conforming to the best practice for standard quality pipe.** Surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale pattern will not be considered defects if the imperfections are removable within the tolerances specified for wall thickness or 0.005 in. [0.1 mm], whichever is the greater. The bottom of imperfections shall be visible and the profile shall be rounded and faired-in.



- **SSTD-8070-0060-PIPE- Standard for Low Pressure Pipe System for Liquid Oxygen “AA”**
  - Does not specify surface finish minimum
- **SSTD-8070-0069-PIPE -Standard for Low Pressure Vacuum Jacketed Pipe**
  - The surface finish on all internal, service media wetted surfaces and weld end preparation surfaces of boss fittings shall be 250 RMS or smoother.
- **SQP-5300-0079- Quality Book 3, Warehouse/Receipt Inspection/ Procurement Process Support**
  - Perform a visual inspection of all piping and tubing to verify that the internals are smooth and are free of de-laminations, rough appearances or burrs (it is understood that not all internal surfaces will be accessible for visual inspection). To better gauge the finish a micro finish comparator should be used and the finish should not have a surface roughness greater than 250P or 250 ST. Quality Engineering shall be notified of any suspect defective materials.

# Inspecting Surface Finish



- SSC currently uses a micro finish comparator to gauge surface roughness



# LOX Pipe vs. LH Pipe



**Spare LOX Spool**



**Spare LH Spool**

## Recommendations



# DISCUSS WITH FOD TEAM

- **How does SSC address roughness and surface finish on future pipe procurements?**
  - Specify a minimum roughness value of 250 RMS?
  - Specify a specific surface finishing procedure?
  - Description of desired surface finish?
  - Quote text from ASTM A999
    - Pipe shall be uniform in quality and condition and have a finish conforming to the best practice for standard quality pipe.
  - Pictures of acceptable vs. unacceptable surface finishes?
  - Want to be careful on specifying things that will drive up cost significantly
  - Discuss this with pipe suppliers

# A-1 LOX & LH Runline Contamination

## Findings



- **Team was able to replicate on stand fiber contamination utilizing remnant piping spools and on site rags**
- **Fibers were introduced into piping via cotton rags (possibly white rags with red or blue stripes) utilized during normal fabrication tasks (machining, welding, etc)**
  - **Runline fibers consistent with rag fibers:**
    - **Cotton Material, Highly Fluorescence, Similar Size**
  - **Internal surface of runline piping/fittings increased probability of fiber attachment**
    - **Rough surface finish, raised areas, sharp edges, etc**
  - **No evidence of rag remaining in A-1 LOX/LH system**
- **Not all fibers removed during normal pipe cleaning**
  - **Rough surface of piping inhibited cleaning**
- **Remaining fibers still attached after cleaning were not dislodged during final solvent flush inspection, therefore piping passed cleaning certification**
- **After piping installation, some fibers dislodged by runline purges and/or coldshock**
- **Loose fibers in LH runline migrated to LH runline screen via purge flow.**

# A-1 LOX & LH Runline Contamination

## Recommendations



- **Evaluate allowable piping internal surface roughness for specific applications (i. e., runlines, etc)**
- **Evaluate procurement process to obtain desired internal surface roughness for piping and fittings**
- **Evaluate type and use of rags in fabrication/installation process**
- **Evaluate cleaning processes for piping and screens, including use of Black Light**
- **Process SSC Waiver to document fiber contamination of A-1 runlines and approve for use**
  - **No evidence of rag left in run systems**
  - **Fibers not detrimental to facility operations**
  - **Requires concurrence from customer**