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Fuel Filter Plugging Issues Stopped Locomotives Cold? – *RESTART* Your Operation!

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Introduction

Back "in the old days," a railroad fuel manager, purchasing petroleum diesel fuel, might be expected to deal with cold temperature wax / 'fuel gelling' in the winter, possibly a bit of water in the spring and maybe some corresponding rust or sediment at various times of the year.

Locomotive fuel systems typically consisted of mechanical injectors with 'relatively' loose tolerances of several ten-thousandths of an inch (10's of microns) and mechanical lift pumps with output pressures of 60-90 psi. These systems would typically run 10-13 micron filtration – as long as the filter was not removed (a dangerous, but historically common practice) to allow gelled fuel to pass in cold weather. The mechanical rocker arm could power through most grit and grime in the fuel and actuate the injector so long as the rack and plunger did not seize completely solid.

The modern fuel landscape has expanded to include biodiesel, renewable diesel fuel, 'synthetic' diesel, various forms of hydro-processed and hydrotreated oils and (hopefully minimal) amounts of hydro-treated viscous oil and/or raw vegetable oil.

Modern locomotive fuel systems often consist of electronically actuated high pressure common rail (HPCR) fuel injectors with tolerances in the single micron range and injection pressure of several thousand psi. These systems often *require* filtration down to the single digit micron range as well. The electronic actuation relies on a small electromagnet moving a thumbtack-sized pilot valve to trigger the main injection sequence. Any small amount of grit or abnormal residue in the fuel can delay or prevent the sequence of events for an optimal fuel injection event, leading to poor performance, increased fuel consumption, increased emissions or worst case, no-start or no-run conditions.

These compounding mechanical factors combined with changes in fuel chemistry, advancements in additive chemistry, differences in fuel solvency and many other characteristics mean the typical fuel handler will likely encounter considerably more frequent and considerably more varied issues which may result in fuel filter plugging. Thus, this guide was created.

The Process

If such a fuel filter plugging / flow upset event were to occur, ideally the operator can apply this guide to complete a stepwise process to **"RESTART"** the fuel flow and return operations to normal conditions.

The process is loosely based on the following steps:

(R) Recognize the issue - Recognizing a fuel filter plugging issue would ideally start by noticing slight changes in the fuel supply. However, many times the plugging issue is only noticed after fuel flow stops. The 'Description', 'Conditions which Generate' and 'Conditions which Exclude' points of this guide all help to narrow down which issues are likely and which are unlikely, given a set of operating conditions.

(E) Expect the issue to continue getting worse - In most cases a fuel filter plugging issue will only get worse unless prompt action is taken to remedy the situation. Attempts to 'burn through' or 'use up' contaminated fuel can often lead to further issues in locomotives or other equipment.

(S) Sample - Verbal descriptions and/or guesses at what the plugging issue is are typically not effective ways to find the best solution for the issue. This is why sampling of the fuel filter itself, fuel contained in the filter housing and the general fuel supply are so important. Ideally, historic samples could be referenced to help determine when an issue first appeared in the fuel supply. Then, samples of the current supply will help guide the analysis further. The 'Ideal Samples' point will list the best location to obtain fuel with the highest likelihood of showing the issue.

(T) Test - Testing helps drill down to the ground truth or root cause of the filter plugging issue. This guide provides a wealth of information detailing various laboratory tests and multiple field tests to provide options for either 'on-the-spot' identification, or more refined testing with laboratory instruments. 'Field Tests' can generally confirm or rule out possible issues with basic equipment available on site while 'formal laboratory tests' can specifically confirm or rule out any suspected fuel issue with more advanced equipment.

(A) Action - With firm evidence of a root cause based on rigorous and valid testing, the best method to deal with the filter plugging issue can be determined and an action plan can be put in place. 'Corrective Measures' are listed to aid in the quickest and most cost-effective remediation of the issue. Additionally, 'Not Recommended' steps are listed which have historically proven to be ineffective and/or a waste of time and money.

(R) Resample / Retest - With the action plan in place, improvements in fuel quality should be noted. However, it is important to resample and retest the fuel at this point to ensure quality metrics are being met and the previous action has been sufficient to eliminate the original plugging issue.

(T) – Train / Learn from the issue - Once the filter plugging issue has been successfully mitigated, it is important to learn from the issue as an individual and more importantly, train those around you. Were there early warning signs which were missed? Could additional sampling or different testing have been useful to spot the situation earlier? Could changes to fuel quality specifications result in cleaner fuel? The ultimate goal should be to learn from the issue and help prevent future issues from arising.

To aid in this ***"RESTART"*** process, the following pages are designed as a series of "one-pager" high-level overviews detailing several of the most common fuel filter plugging issues noted in recent history. In addition to the pages here, the pages will be made available for download from the LMOA website as well as a large format color poster for quick reference in any location where fuel is typically handled.

Of important note, this document **does not address any safety concerns, PPE required, or any other precautionary measures** associated with fuel, fuel handling or fuel sampling. We ask the reader of this document to use all proper safety, health, and environmental practices as detailed by your company as well as local, state, and national government regulations.

Additionally, samples taken for laboratory analysis may need to be placed in approved shipping containers and shipped according to applicable laws. In the United States, this may mean Code of Federal Regulations (CFR) 49 Section 173.150 labeling and **ground shipping only**. It is also wise to confer with any testing lab prior to sampling to ensure proper quantities of sample are obtained and proper sampling methods and sample locations are used.

One-Pager Guides

Each of the following pages is broken down with headings and subsections described as follows:

Heading	Description / Definition
Plugging Issue	A short name, colloquial reference or title for the issue affecting the filter.
Conditions which Generate	A list of conditions which are required to generate the filter plugging issue. It is important to note in some cases these conditions apply to "locally, where the fuel is used" and in some cases these conditions apply to "globally, through the entire supply chain" - notes have been supplied for each case. If careful examination and/or testing reveals these conditions are NOT present, then the filter plugging issue can be ruled out or ignored.
Conditions which Exclude	A list of conditions which specifically exclude the filter plugging issue. It is important to note in some cases these conditions apply to "locally, where the fuel is used" and in some cases these conditions apply to "globally, through the entire supply chain" - notes have been supplied for each case. If careful examination and/or testing reveals these conditions ARE present, then the filter plugging issue can be ruled out or ignored.
Image	An image showing 'typical' appearance of the issue. Note that any 'fuel color' depicted (red, yellow, clear, etc.) will depend on *your* local fuel supply and color.
Ideal Samples	Describes the best location and method to obtain fuel samples with the highest possibility of spotting conditions associated with the filter plugging issue. For example, if water is suspected, taking a sample from mid or upper levels of a fuel system or tank may not accurately reveal the presence of water. In this case, a tank bottom sample is preferred and should show any water present.
Formal Laboratory Tests which can Confirm	If discussing the fuel filter plugging issue with a fuel testing laboratory, these are a selection of tests by formal name and/or ASTM number which could be useful in identifying or ruling out properties in the fuel which could lead to the plugging issue. It is also good practice to confer with the testing laboratory to determine appropriate amount of sample and appropriate location to obtain samples.
Field Tests to Confirm	Describes a selection of tests which can typically be performed in the field or on-site, with minimal equipment or simple / commonly available equipment. These tests can often provide a quick go / no-go indication of the filter plugging issue. Laboratory testing is recommended for formal confirmation, and this document does NOT address safety concerns with sampling or testing. Please use all Personal Protective Equipment (PPE) and Standard Operating Procedures (SOP) as outlined by your employer. If in doubt, ask for additional guidance.
Limits / Guidelines	A selection of guidelines and specification limits for results obtained through fuel testing. Fuel meeting these guidelines would generally be considered "in specification", while fuel outside these guidelines may result in filter plugging issues.
Corrective Measures	Recommended corrective measures and actions which should restore fuel and fuel flow to normal operations. These measures include mechanical and maintenance procedures as well as chemical and additive suggestions which may improve fuel quality.
Not Recommended	Common "fixes" or "remedies" which are based on misconception, "folklore", "wives' tales" or other inaccurate sources of information.

Classic Wax / Cold Temperature Fuel Gelling

A fuel filter displaying a typical build-up of wax during a winter cold season.

Classic Wax / Cold Temperature Fuel Gelling

Cold Temperature Fuel Gelling resulting from operation in temperatures below Cloud Point (CP) and at or below Cold Filter Plugging Point (CFPP) of the fuel. Crystals of paraffin wax accumulate on the filter surface.

Conditions which Generate

- Fuel operating in ambient temperatures below Cloud Point (CP) of fuel and near or below Cold Filter Plugging Point (CFPP).
- Fuel with higher paraffin content (normal alkanes) - common in 'summer diesel' and renewable diesel.
- Poorly insulated tanks, exposed lines, or filter housings.

Conditions which Exclude

- Fuel operating in ambient temperatures above CP of fuel.
- Fuel treated with effective cold-flow improvers prior to crystallization.
- Systems with adequate recirculation or heating to keep the fuel above critical temperatures.

Ideal Samples

- Samples taken from fuel prior to gelling and with any additives thoroughly mixed will generate the most accurate test data.
- Samples of fuel containing existing wax or gel may show abnormally high temperature cold-flow properties.

Formal Laboratory Tests which can Confirm

- ASTM D2500, D5773, D7689 - Cloud Point
- ASTM D6371 - Cold Filter Plugging Point
- ASTM D4539 - Low Temperature Flow Test

Field Tests to Confirm

- Fuel sample in a transparent glass container, at operating ambient temperature, looks cloudy.
- Fuel warmed above CP should return to 'clear and bright' appearance.
- Samples of plugging material from filter should liquefy when warmed above CP, normally will also return to a clear liquid.

Limits / Guidelines

- Cloud Point should ideally be at least 10°F (6°C) below expected ambient minimum operating temperature.
- CFPP should be below the coldest expected operating temperature.
- Use of seasonally appropriate fuel (winter diesel) recommended by suppliers.
- Typically, northern regions will have more stringent requirements than southern and coastal regions.

Corrective Measures

- Warm fuel above CP. If fuel must operate in cold conditions a cold-flow improver additive should be used and ideally applied and thoroughly mixed in the fuel BEFORE cold temperatures are experienced.
- Carefully consider levels of biodiesel and renewable fuel added to petroleum diesel fuel exposed to cold weather operation.
- In extreme low temperatures, partial or full substitutions with No. 1 diesel may be needed.

Not Recommended

- Methanol or gasoline as an additive - both are ineffective at lowering CP / CFPP of the fuel and may reduce flash point to dangerous levels.
- Removing fuel filter. While this can restore fuel flow, it also allows damaging particulates to flow through the fuel system.
- “Magnetic” or “electronic” anti-gelling devices — no scientific evidence of effectiveness.

Cold Temperature Filter Icing

Image of ice accumulation on a fuel filter. Note the general lack of color and the ice appears mainly 'snow white'.

Cold Temperature Filter Icing

Fuel which includes elevated water content and is operated in temperatures below the freezing point of water (32°F / 0°C). Free water in fuel freezes and accumulates on filter surfaces.

Conditions which Generate

- Fuel containing free water and fuel temperatures below 32°F / 0°C

Conditions which Exclude

- Fuel operating in ambient temperatures above 32°F / 0°C. (May still contain water) Or systems consistently maintained in a known water-free state.

Ideal Samples

- Sample fuel from bottom of tank, water separator or other low-lying points. Bottom of tank (drain valves).
- Fuel return lines (recirculated, high-temp fuel promotes water suspension).
- Post-primary filter sample ports (to test system efficiency).

Formal Laboratory Tests which can Confirm

- ASTM D2709 - Water and Sediment (Centrifuge)
- ASTM D6304 - Water by Karl Fischer
- ASTM D4176 - Procedure 2 - Visual Appearance

Field Tests to Confirm

- Samples of plugging material from filter should liquefy in a very narrow temperature range when warmed above 32°F / 0°C.

Limits / Guidelines

- Maintain water ≤0.05% (500 ppm) per ASTM D975. For critical systems, ≤200 ppm water.
- Free water in tanks should be undetectable with routine bottom draining.
- Many OEMs require functioning water-separating filters on locomotives and regular service / drain intervals.

Corrective Measures

- Drain tank bottoms, water separators, and low points until only “clear and bright” fuel flows.
- Inspect and maintain seals, vents, and gaskets to minimize water ingress.
- Periodic water checks and use of desiccant breathers or tank blanketing in humid climates.

Not Recommended

- Adding alcohol-based “dry gas”: harmful to diesel systems, can reduce lubricity, and may carry water through to injectors.
- Cold-flow (anti-gel) additives do not prevent icing — they address wax, not water.
- “Just run it harder” — high return-fuel temperatures may temporarily help, but filter icing often occurs before the engine can warm up.

Bacteria / Algae Growth

A fuel filter plugged with a bacterial colony (left). Typical new fuel filter (right).

Bacteria / Algae Growth

Biological growth at the fuel-water interface due to the presence of water and naturally occurring yeast/fungus/bacteria in the fuel. Growth produces a biofilm, organic acids and other debris that plug filters and corrode tanks.

Conditions which Generate

- Presence of free water from condensation, water ingress, or poor tank maintenance.
- Long storage times, especially in warm or humid environments.
- Low flow or stagnant fuel systems where biofilms can establish and thicken.

Conditions which Exclude

- Fuel which is proven to be below specification ranges for suspended water content and contains no free water.
- Proper tank maintenance / regularly drained tank bottoms to keep the fuel dry.
- Systems with continuous fuel turnover, minimizing stagnation.

Ideal Samples

- Tank bottom water phase — the most reliable location to detect active growth.
- Filter housings — slime, black/brown biomass, or gel-like debris are strong indicators.
- Fuel/water separator sumps — often accumulate microbial mats and concentrate any free water in the system.

Formal Laboratory Tests which can Confirm

- ASTM D2709 – Water and Sediment (Centrifuge)
- ASTM D6304 - Water by Karl Fischer
- Microbial contamination by ATP

Field Tests to Confirm

- Total Microbial Count / Total Fungal Count dip slides, Adenosine Triphosphate (ATP) test kits.

Limits / Guidelines

- Maintain water ≤0.05% (500 ppm) per ASTM D975. For critical systems, ≤200 ppm.
- Microbial growth action threshold typically $>10^3$ CFU/mL (colony forming units per milliliter).

Corrective Measures

- Drain/remove all free water from tanks and low points. Treat with an EPA-registered biocide at shock dose.
- Polish/recirculate fuel through coalescers and filters to remove dead biomass.
- Establish regular monitoring of fuel.

Not Recommended

- Attempting to “burn through” contaminated fuel without treatment (can cause injector fouling and corrosion).
- “Enzyme treatments” or “fuel conditioners” alone do not kill microbes — only true biocides do.
- Alcohols do not eliminate microbial colonies and can damage parts and reduce lubricity.

Suspended Water

Typical "clear and bright" fuel sample (left). Cloudy sample with suspended water (right).

Suspended Water

Water becomes finely dispersed as microscopic droplets of 'haze' in diesel fuel due to mechanical agitation, surfactants, biodiesel components, or certain additives. Droplets remain suspended instead of settling, leading to haze.

Conditions which Generate

- Can occur in pretty much any fuel storage or transport scenario OTHER THAN fuel held in known and proven air-tight and water-tight conditions.
- Presence of natural emulsifiers, including biodiesel (FAME) which increases water solubility.
- Rapid temperature decrease causing dissolved water to drop out as a fine dispersion rather than forming free water.

Conditions which Exclude

- Systems using effective demulsifying additives, enabling water to coalesce and separate.
- Fuel maintained at stable temperatures, avoiding rapid cooling.

Ideal Samples

- Sample fuel from bottom of tank, water separator or other low-lying points. Bottom of tank (drain valves).
- Fuel return lines (recirculated, high-temp fuel promotes water suspension).
- Post-primary filter sample ports (to test system efficiency).

Formal Laboratory Tests which can Confirm

- ASTM D2709 - Water and Sediment (Centrifuge)
- ASTM D6304 - Water by Karl Fischer
- ASTM D4176 - Procedure 2 - Visual Appearance

Field Tests to Confirm

- Clear jar "haze observation" — cloudy or milky appearance indicates suspended water.
- Sides of glass jar may appear 'grainy' or 'speckled' due to adhered water droplets.
- Water-finding paste on tank sticks shows free water, helping differentiate suspended vs. free water.
- Coalescer filter performance — rapid plugging or bypass may indicate emulsified water load.

Limits / Guidelines

- Maintain water ≤0.05% (500 ppm) per ASTM D975. For critical systems, ≤200 ppm.
- Free water in tanks should be undetectable with routine bottom draining.
- ASTM D4176 - Rating "2", maximum

Corrective Measures

- Locomotives often have multi-stage filtration (primary, secondary, coalescer) designed to strip suspended water.
- Use of demulsifiers so droplets coalesce and drop to the sump.
- Keep fuel warm in cold climates so water separates faster.

Not Recommended

- Adding alcohols (isopropanol, methanol): increases water solubility but harms lubricity and can carry water to injectors.
- Cold-flow or anti-gel additives do not address suspended water haze.
- Letting the system "run through it" — suspended water can damage injectors and cause corrosion.
- Suspended water will NOT settle to the bottom of the tank, even with extended periods of time (unlike free water).

Free Water

Fuel sample showing two distinct layers – rusty water (bottom), dull, red cloudy fuel (top). An intermediate brown/black 'rag layer' of biologic growth is also noted at the fuel/water interface.

Free Water

Water enters the fuel system and separates from diesel due to immiscibility, settling at tank bottoms or low points.

Conditions which Generate

- Arises from condensation, rainwater ingress, leaking vents/caps, or contaminated deliveries.
- Tanks exposed to humidity, rain, poor seals, or underground tank infiltration.
- Fuel with low demulsifying performance allows water to separate more readily.

Conditions which Exclude

- Tanks kept full or nearly full, minimizing air volume and condensation.
- Use of demulsifiers that keep water from forming stable droplets (but still allow settling).
- Tanks with intact vents, caps, gaskets, and no structural leaks.

Ideal Samples

- Sample fuel from bottom of tank (drain valves), water separator or other low-lying points.
- Post-primary filter sample ports (to test system efficiency).
- Samples from these points should be taken into transparent glass jars for visual "haziness" inspection.

Formal Laboratory Tests which can Confirm

- ASTM D2709 - Water and Sediment (Centrifuge)
- ASTM D6304 - Water by Karl Fischer
- ASTM D4176 - Procedure 2 - Visual Appearance

Field Tests to Confirm

- Clear jar "multiple layer" observation — two layers (fuel above, water below) indicate free water.
- Water-finding paste on tank sticks shows free water, helping differentiate suspended vs. free water.

Limits / Guidelines

- Maintain water ≤0.05% (500 ppm) per ASTM D975. For critical systems, ≤200 ppm.
- Free water in tanks should be undetectable with routine bottom draining.
- ASTM D4176 - Rating "2", maximum

Corrective Measures

- Routinely drain tank bottoms, water separators, and low points until only "clear and bright" fuel flows.
- Inspect and maintain seals, vents, and gaskets to minimize water ingress.
- Periodic water checks and use of desiccant breathers or tank blanketing in humid climates.

Not Recommended

- Using water-emulsifying additives (forces water through injectors, pumps, and causes wear).
- Relying solely on filter/separator replacement without addressing tank water source.
- Anti-gel additives — do not remove or reduce free water.

Monoglycerides

A sample of monoglyceride material removed from a fuel filter. The sample shows a 'greasy', 'mashed potatoes' or 'toothpaste' like appearance and is stable at room temperature.

Monoglycerides

Fuel with a biodiesel component containing elevated monoglyceride (MG) levels, exposed to cool temperatures (typically <40°F / 4°C) for moderate time periods (24 hours+) causing monoglyceride precipitation.

Conditions which Generate

- Fuel must contain some percentage of biodiesel. Higher blends (B10, B20+) are more susceptible to MG precipitation.
- Cold temperatures near or below the monoglyceride crystallization point (commonly 20–40°F / –7 to 4°C).
- Fuel from processing plants with insufficient catalyst removal, poor wash cycles, or incomplete reaction conversion.

Conditions which Exclude

- No biodiesel component in the fuel or fuel has not reached temperatures below 40°F / 4°C.
- Fuel sourced from high-quality (BQ-9000) biodiesel producers distilling fuel to meet ASTM D6751 monoglyceride limits.
- Use of winterized biodiesel where monoglycerides are reduced through cold-soaking and filtration.

Ideal Samples

- Filter inlet sample — captures crystallized monoglycerides directly responsible for plugging.
- Bulk tank bottom and mid-level samples — monoglycerides may settle over time and stratify.
- Fuel polishing system filters or vehicle filter housings — often accumulate visible monoglyceride solids.

Formal Laboratory Tests which can Confirm

- ASTM D7371 or InfraCal Biodiesel Analysis - To confirm biodiesel in fuel
- ASTM D6584 - Glycerin / Glyceride Content of Biodiesel
- ASTM D7501 - Cold Soak Filtration Test

Field Tests to Confirm

- Samples from filter may have a 'greasy', 'toothpaste', or 'mashed potatoes' look and consistency.
- Samples of plugging material from filter will not liquefy when warmed above fuel CP.
- Monoglycerides typically have a melting point of 160°F / 70°C or higher.

Limits / Guidelines

- ASTM D6751 (U.S. Biodiesel Standard): Requires biodiesel to have total glycerin ≤0.24 wt.% and monoglycerides ≤0.4 wt.%.
- EN 14214 (European Standard): More stringent — monoglycerides ≤0.8% at 10% distillation residue and ≤0.7 wt.% overall.
- Cold Soak Filtration Test (CSFT): ASTM D6751 mandates passing CSFT at 4.5°C to ensure biodiesel blends remain filterable.

Corrective Measures

- Work with suppliers to ensure biodiesel meets ASTM D6751/EN 14214 and passes cold soak filtration requirements.
- Increase fuel turnover to prevent long-term storage in cold conditions.
- In cold climates, use winterized diesel or limit biodiesel % in fuel.

Not Recommended

- Cold-flow improvers (CFIs) used for petroleum wax do not dissolve monoglycerides.
- Biocides have no effect — monoglyceride crystals are not biological.
- Monoglycerides do not melt at typical fuel temperatures. Solids settle and require mechanical removal.

Sterols / Steryl Glucosides

Steryl glucosides in a fuel filter housing. The material displayed a grainy gel-like consistency and was tinted with the predominant color of the fuel (red dye). The material was thermally stable on a hot summer day.

Sterols / Steryl Glucosides

Steryl glucosides (SG) in fuel with a biodiesel component containing elevated levels of plant sterols that survive the biodiesel transesterification process.

Conditions which Generate

- Fuel must contain some percentage of biodiesel, typically 5% biodiesel or higher.
- Biodiesel produced from soy, canola, and other vegetable oils high in sterol content.

Conditions which Exclude

- No or low (<B5) biodiesel component in the fuel.

Ideal Samples

- Samples of material trapped and concentrated on fuel filter can help identify material composition and source.
- Bulk tank bottoms— SG solids settle slowly but accumulate over time.

Formal Laboratory Tests which can Confirm

- ASTM D7371 or InfraCal Biodiesel Analysis - To confirm biodiesel in fuel.
- ASTM D7806 - Biodiesel Content in Fuel (1-40%)
- Advanced chromatography (HPLC/GC-MS) for sterol glucosides
- Sterol Glucoside Quantification by HPLC or GC — specialized method used by biodiesel QC labs

Field Tests to Confirm

- Plugging material from filter will have a red or yellow (typically same color as fuel) gel-like appearance.
- Material will not melt at warm temperatures and will be fully stable even at warm ambient temperatures (100°F / 38°C).

Limits / Guidelines

- ASTM D6751 does not include a sterol glucoside limit, but industry best practice targets < 20 ppm for trouble-free performance.
- ASTM D7501 - CSFT - Fuel should pass standard filtration time limits (≤ 360 seconds for B100 before blending).

Corrective Measures

- Remove and replace affected fuel with biodiesel meeting ASTM D6751 cold soak filtration and SG quality requirements.
- Work with supplier to identify and eliminate off-spec biodiesel batches (quality assurance on feedstock processing).
- Increase fuel turnover to reduce long-term storage of biodiesel blends.

Not Recommended

- CFIs / anti-gel additives used for petroleum wax do not dissolve SG particles.
- SGs melt only at extremely high temps (often > 200°F / 93°C).
- Most detergents do not clean SG's.

Pipeline Drag Reducing Agent (DRA)

Pipeline Drag Reducing Agent (DRA) forms a slimy gel-like coating on the fuel filter media. The coating can form string-like filaments if the filter pleats are squeezed together then slowly pulled apart.

Pipeline Drag Reducing Agent (DRA)

DRAs are long-chain polymer additives used in pipelines to reduce friction and increase flow rate. The polymer chains form gel-like fragments that accumulate on filters and cause plugging.

Conditions which Generate

- Fuel has been transported through a pipeline at some point in the delivery process. Note that local distributors or other upstream locations may transport through pipeline even though local delivery is by tank truck.
- Pipeline batching where product interfaces are not cleanly cut, carrying DRA into finished fuel.
- Terminal operations where tank mixing is insufficient, and DRA concentrates in dead zones.

Conditions which Exclude

- Fuel has never been transported in a pipeline through the entire logistics chain between refinery and your storage.
- Terminals receiving fuel directly from refineries or tank farms without pipeline DRA injection.
- Fuel has passed through coalescing filtration with no unusual pressure rise or gel-like solids.

Ideal Samples

- Samples of material trapped and concentrated on fuel filter can help identify material composition and source.
- Tank bottoms: Heavier DRA may settle here; great for contamination detection.
- After pipeline delivery: Sample during or immediately after receiving fuel to catch incoming DRA.

Formal Laboratory Tests which can Confirm

- ASTM D2068 – Filter Blocking Tendency (FBT)
- ASTM D5296 – Molecular Weight Determination
- ASTM D7872 – Determination of DRA Concentration
- FTIR Spectroscopy (Non-ASTM) - Identifies functional chemical groups in unknown residues, helping pinpoint the presence of polymer-based additives.

Field Tests to Confirm

- Isolate several pleats of the filter and squeeze the pleats together under moderate pressure between finger and thumb. On pulling the pleats apart, look for long, stringy filaments of DRA stretching between the filter pleats.

Limits / Guidelines

- No formal ASTM limit for DRA contamination, but fuel should contain zero detectable polymeric material.
- Typical treat rates are single-digit parts per million (e.g., <10ppm), even slightly higher treat rates can cause issues.
- Some terminals adopt internal thresholds using filterability index (ASTM D2068) as early detection.

Corrective Measures

- Source control: Engage supplier/pipeline operator to confirm DRA dosing levels and verify additive QC practices.
- Monitoring: Add ASTM D2068 (FBT) or ASTM D6217 testing to receiving fuel quality checks when filter plugging is suspected.
- Communication: Document and report contamination events to both supplier and end-user maintenance teams to prevent recurrence.

Not Recommended

- Cold-flow additives — do not break down or prevent DRA polymer accumulation.
- Heating — DRA does not melt at fuel-relevant temperatures.
- Detergents/dispersants/emulsifiers — these can interact with DRAs and worsen polymer precipitation.
- Ignoring early filter plugging – may lead to the situation rapidly worsening.

Fuel System Degradation

Interior of a rubber fuel hose is cracked and brittle after exposure to alternate diesel fuel blends.

Fuel System Degradation

Gasket, hose, o-ring or other 'soft part' breakdown due to age or exposure to incompatible fuels. Certain elastomers (e.g., nitrile rubber, natural rubber, etc. are more susceptible.

Conditions which Generate

- Use of high-FAME biodiesel blends (B20, B50, B100).
- Transition from high-aromatic ULSD diesel to low aromatic renewable diesel, leading seals to shrink and lose sealing force.
- Cycling between alternate diesel fuels listed above and normal petroleum diesel.
- Older equipment with non-fluoro elastomer seals (pre-mid-1990s designs).

Conditions which Exclude

- Fuel system provably and historically known to be operated on fuel within OEM specifications with regard to any alternate diesel fuel content.
- Fuel systems that have not undergone rapid fuel-type transition, allowing steady-state swell behavior.
- Use of low-blend biodiesel (B2–B5) / low renewable diesel, combined with compatible elastomers.
- New/modern components made of advanced polymers.

Ideal Samples

- Samples of material trapped and concentrated on fuel filter can help identify source.
- Samples of the typical fuel flow can help identify overall concentration of particulates in the fuel as well as average biodiesel / renewable diesel levels.

Formal Laboratory Tests which can Confirm

- ASTM D7371 or InfraCal Biodiesel Analysis - To confirm biodiesel in fuel.
- ASTM D7806 - Biodiesel Content in Fuel (1-40%)
- ASTM D6866 - Biogenic Carbon - Renewable diesel + Biodiesel content

Field Tests to Confirm

- Visual inspection of removed hoses, o-rings, and gaskets for signs of swelling, cracking, or brittleness. Black, granular material concentrated on filter media.

Limits / Guidelines

- Locomotive OEMs generally approve B5 / R30 widely, B20 / R50 conditionally, and require certification for higher blends.
- Biodiesel blends must meet ASTM D7467 (B6–B20) or ASTM D6751 (B100) and be verified against OEM material compatibility charts.
- Best practice: Use elastomer materials rated for biodiesel/renewable fuels (e.g., Viton®, fluorocarbon elastomers).

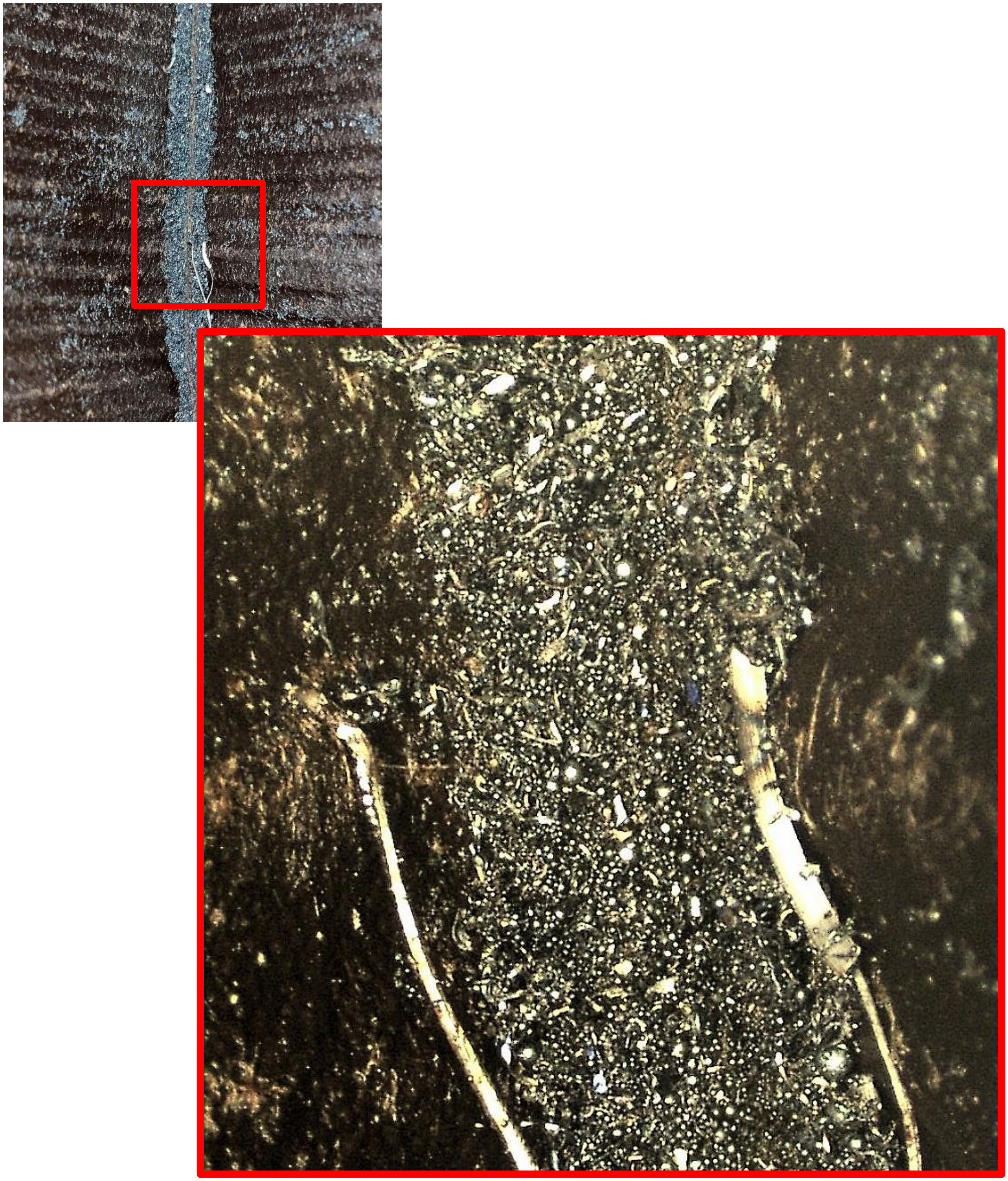
Corrective Measures

- Replace degraded seals, hoses, and o-rings with OEM-approved, fuel-compatible materials.
- Limit long-term storage of biodiesel blends (to reduce exposure to oxidative byproducts that attack elastomers).
- Regular inspections of fuel system components during maintenance intervals.

Not Recommended

- Continuing to operate with degraded gaskets or hoses (leak risk, contamination).
- Additives or 'stop leak' does not restore damaged seals — elastomer damage is irreversible.
- Using unapproved aftermarket elastomer materials not rated for biodiesel or renewable diesel.

Fuel System Construction / Repair Debris



Grinding dust, cutting chips and a wire wheel whisker were noted on a fuel filter after cutting, cleaning, and welding operations were performed on a fuel tank. (The lack of rust on the debris does suggest the fuel was otherwise dry.) Note round globules of metal – sparks and slag which solidified in mid-air.

Fuel System Construction / Repair Debris

Metal cutting chips, grinding/welding slag, Teflon tape, polymer sealant, etc. from constructing / maintaining fuel system.

Conditions which Generate

- Known construction or maintenance work at any point upstream of the filter. Can be either locally, on tanks, pipes, or other infrastructure, or extend to upstream pipeline, and delivery facilities.

Conditions which Exclude

- Systems with no recent maintenance or disturbance and historically clean operations.

Ideal Samples

- Samples of material trapped and concentrated on fuel filter can help identify source.
- Samples of the typical fuel flow can help identify overall concentration of particulates in the fuel.

Formal Laboratory Tests which can Confirm

- ASTM D6217 – Particulate Contamination (gravimetric)
- ASTM D5185 – Metal content by ICP-OES
- FTIR (for polymer/sealant residue identification)

Field Tests to Confirm

- Visual or low-power magnification inspection of filter pleats for metallic or polymeric debris.
- Magnet test for ferrous metal shavings.
- Clear jar test - visible floating particles or particles settling at bottom.

Limits / Guidelines

- ASTM D975 (diesel fuel) requires clear & bright fuel.
- ASTM D6217 - Gravimetric particulate contamination ≤24 mg/L.
- ISO 4406 cleanliness codes often applied for high-reliability systems (hydraulics/locomotives).

Corrective Measures

- Flush tanks, lines, and piping after maintenance/construction before returning to service.
- Work with upstream suppliers to enforce cleanliness standards.
- Use tank inspection cameras or bottom sampling after major work to confirm system cleanliness.

Not Recommended

- Magnetic devices only capture ferrous debris — not aluminum, stainless, brass, or sealant fragments.
- Additives are ineffective.

Rust and Oxidative Corrosion

Rust flakes and other oxidation debris removed from a fuel filter. (Ball point pen, left, for scale)

Rust and Oxidative Corrosion

Rust forms when water and oxygen contact steel surfaces, producing iron oxides that flake into the fuel system as particulates. Corrosion accelerates when free water stands in tank bottoms,

Conditions which Generate

- Most fuel tanks naturally "breathe" with temperature swings, pulling in moist air, condensation forms on tank walls.
- Long lay-ups or storage in humid/cold climates accelerate the process.
- Older steel tanks with compromised internal coatings.

Conditions which Exclude

- Systems consistently maintained water-free, fitted with desiccant breathers, and drained at low points during inspections.
- Non-metallic tanks (fiberglass, poly) or internally lined steel tanks.
- Systems maintained with minimal air exposure and full tank levels.

Ideal Samples

- Samples of material trapped and concentrated on fuel filter can help identify source.
- Samples of the typical fuel flow can help identify overall concentration of particulates in the fuel.

Formal Laboratory Tests which can Confirm

- ASTM E1508 - Elemental determination by EDS
- ASTM D2709 - Water and Sediment (Centrifuge)
- ISO 4406 - Particle Count

Field Tests to Confirm

- Visual inspection of fuel filters which may confirm reddish-brown, powdery debris.
- Clear jar samples which may contain settling rust particles.
- Magnet check to confirm ferrous nature of debris.

Limits / Guidelines

- Fuel should contain zero visible particulate under clear & bright inspection.
- ISO 4406 cleanliness typically targeted from ISO 18/16/13 down to 12/9/6 or cleaner for modern diesel systems.
- Many OEMs require ≤ 10 µm filtration for final fuel at point of use.

Corrective Measures

- Drain tank bottoms regularly during yard servicing to remove water and rust sediment.
- Retrofit or specify Viton® seals and coated components for improved chemical resistance.
- Train operators/maintenance staff to check "clear & bright" at fueling stations.

Not Recommended

- Using dispersants that push rust deeper into injectors.
- Extending filter change intervals when rust is present.
- "Magnetic filtration" - does not remove non-ferrous corrosion debris and may not remove some ferrous oxides.

Microbially Induced Corrosion (MIC)

Appearance of microbially induced corrosion (MIC) inside a steel pipe. Note the round nodules, aka 'blisters', and some pitting formed by microbial colonies in contrast to standard 'rust flakes' of normal oxidative corrosion.

Microbially Induced Corrosion (MIC)

Microbial waste products include volatile acids which can lead to corrosion of various metal fittings. May affect metals other than steel, such as stainless steel, and appear different than standard 'rust' corrosion.

Conditions which Generate

- Fuel with water content above specification can generate biological growth.

Conditions which Exclude

- Systems consistently maintained water-free, fitted with desiccant breathers, and drained at low points during routine inspections.
- Non-metallic tanks (fiberglass, polyethylene) or internally lined steel tanks.
- Systems maintained with minimal air exposure and full tank levels.

Ideal Samples

- Samples of material trapped and concentrated on fuel filter can help identify source.
- Filter housings — often contain MIC debris, sticky black sludge, or sulfurous odors.
- Fuel/water separator bowls, which accumulate biomass and corrosive byproducts.

Formal Laboratory Tests which can Confirm

- ASTM D2709 - Water and Sediment (Centrifuge)
- ASTM D6304 - Water by Karl Fischer
- Microbial contamination by ATP

Field Tests to Confirm

- Total Microbial Count / Total Fungal Count dip slides.
- Adenosine Triphosphate (ATP) test kits, or visual inspection of slime at tank bottoms.
- Water-finding paste to detect standing water.

Limits / Guidelines

- Maintain water ≤0.05% (500 ppm) per ASTM D975. For critical systems, ≤200 ppm.
- Free water in tanks should be undetectable with routine bottom draining.
- ASTM D4176 - Rating "2", maximum

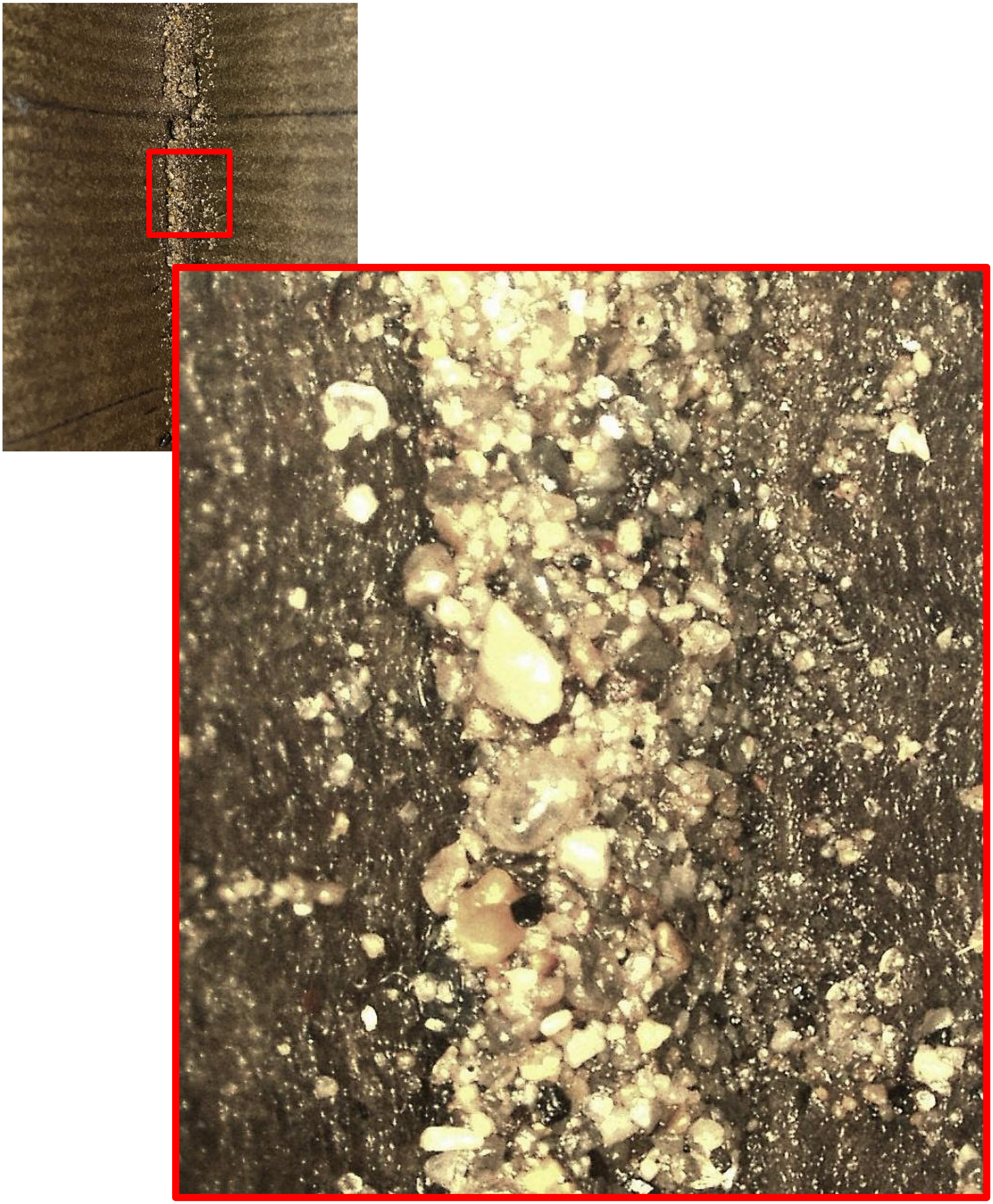
Corrective Measures

- Routinely drain tank bottoms, water separators, and low points until only “clear and bright” fuel flows.
- Inspect and maintain seals, vents, and gaskets to minimize water ingress.
- Periodic water checks and use of desiccant breathers or tank blanketing in humid climates.

Not Recommended

- Biocides alone won’t fix MIC if water remains — mechanical removal of water and sludge is essential.
- Additives claiming to “disperse” microbes do not eliminate colonies or stop corrosion.
- Magnetic devices offer zero benefit; MIC is a chemical/biological process.

Sand and Dirt – Atmospheric Contamination



Granules of sand and windblown dirt trapped on a filter.

Sand and Dirt – Atmospheric Contamination

Fuel system exposed to air or contamination through tank vents, missing or open caps, broken vent hoses, etc.

Conditions which Generate

- Locomotive fuel tanks exposed to unsealed vent lines or defective caps.
- Refueling operations performed in dusty environments without protective controls.
- Poor filtration at bulk fuel storage or fueling stations.
- Fuel nozzles and hoses dragged on the ground or left open/uncapped during transport.

Conditions which Exclude

- Fuel systems with sealed tanks, intact vent hoses/caps, and fuel sourced from well-maintained, filtered storage.
- Use of desiccant breathers or particulate filters on tank vents.
- Rigorous housekeeping around fill ports and loading racks.

Ideal Samples

- Samples of material trapped and concentrated on fuel filter can help identify source.
- Samples of the typical fuel flow can help identify overall concentration of particulates in the fuel.
- Samples from tank bottoms — sand and dirt settle quickly due to high density.

Formal Laboratory Tests which can Confirm

- ASTM D5185 – Metal content by ICP-OES
- ASTM E1508 – Elemental determination by EDS
- ASTM D6217 – Gravimetric particulates.
- ISO 4406 – Particulate Count

Field Tests to Confirm

- Clear & bright jar test - visible grit at bottom after settling.
- Simple “rub test” of filter debris - gritty feel indicates silica/dirt.
- Magnet test — useful for separating rust from sand; sand will not adhere.

Limits / Guidelines

- Fuel should contain zero visible particulate under clear & bright inspection.
- ISO cleanliness typically targeted from ISO 18/16/13 down to 12/9/6 or cleaner for modern diesel systems.
- Many OEMs require ≤ 10 µm filtration for final fuel at point of use.

Corrective Measures

- Ensure fuel storage tanks and fueling stations are filtered and capped.
- Use fine-micron fuel filters (10 µm or finer) with regular monitoring of differential pressure.
- Conduct bulk fuel filtration (polishing) before transfer to locomotives.

Not Recommended

- Attempting to use dispersants — solids must be physically removed, not “treated.”
- Relying solely on locomotive filters; bulk storage filtration is critical.

Disturbed Sediment

Appearance of sediment which ‘suddenly plugged’ a locomotive fuel filter after a hard switching event. The fuel was ‘normal’ until the impact stirred sediment from the bottom of the tank.

Disturbed Sediment

Sediment which typically remains near the bottom of the tank, or adhered to tank/pipe walls is disturbed and enters the normal fuel flow.

Conditions which Generate

- Tanks in long-term service which may accumulate considerable amounts of sediment.
- Vibrations/shock loads from switching, track impacts, derailment, or tank cleaning, or other action which may cause turbulence in the fuel tank.
- Pipeline pigging or refueling operations that introduce sediment from upstream.

Conditions which Exclude

- Recently cleaned tanks and systems with consistent fuel turnover and filtration. Preventive draining and fuel polishing that keeps bottoms free of accumulated sediment.
- New equipment and tanks which have not had time to accumulate sediment.

Ideal Samples

- Samples of material trapped and concentrated on fuel filter can help identify source.
- Samples of the typical fuel flow can help identify overall concentration of particulates in the fuel.

Formal Laboratory Tests which can Confirm

- ASTM D6217 – Gravimetric particulates
- ASTM D2276 – Particulate contamination by membrane filtration
- ISO 4406 – Particle Count

Field Tests to Confirm

- Jar test – fuel should be clear & bright with no obvious settling of heavy solids after a brief time.
- Filter inspection – layered deposits of dark sediment or rust and scale may indicate material from tank bottom.

Limits / Guidelines

- Fuel should contain zero visible particulate under clear & bright inspection.
- ISO cleanliness typically targeted from ISO 18/16/13 down to 12/9/6 or cleaner for modern diesel systems.
- Many OEMs require ≤ 10 µm filtration for final fuel at point of use.

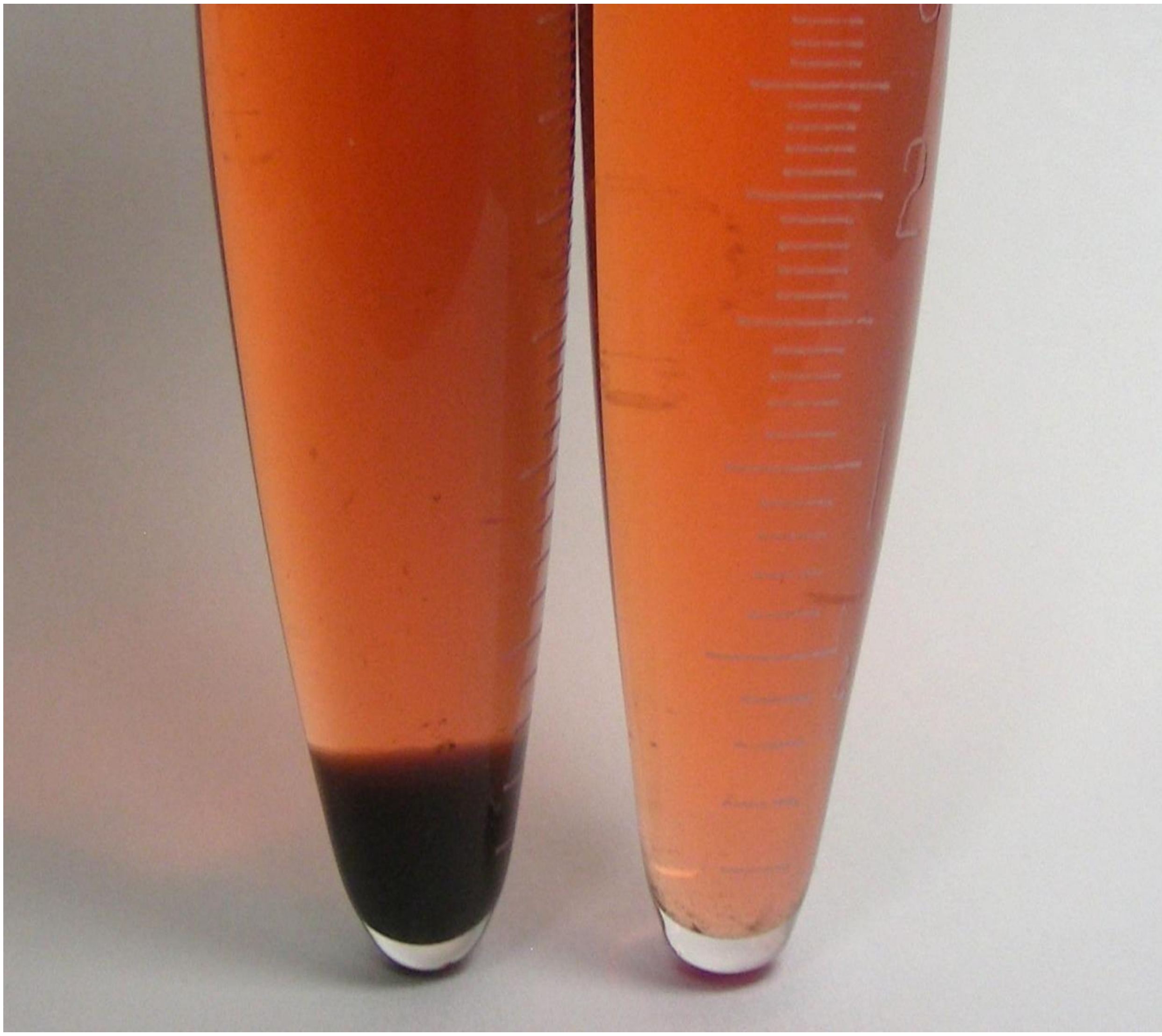
Corrective Measures

- Zero visible sediment tolerated.
- Particulates must be below 24 mg/L (ASTM D6217).
- Fuel polishing/recirculation filtration during layups or when contamination suspected.
- Use micro-glass or coalescing filters (10 µm or finer) in fueling stations to prevent sediment transfer deeper into fuel systems.

Not Recommended

- Using dispersants that push rust deeper into injectors.
- Using dispersants that re-suspend sediment and push solids deeper into injectors.

Fuel Additive Cross Reaction



Cross reaction of two additives in fuel (left). The reaction originally produced a virtually unnoticeable brown haze in the fuel (right). After five minutes in a centrifuge, or a few days undisturbed in a tank, a brown, flocculent material settled to the bottom of the fuel.

Fuel Additive Cross Reaction

When additives from different manufacturers are mixed, their chemistries can interact, forming precipitates, gels, or insoluble complexes that plug filters. Common triggers include detergent + demulsifier conflicts.

Conditions which Generate

- Use of multiple additives from different suppliers without coordination.
- Overdosing beyond OEM or ASTM recommended treat rates.
- Blending biodiesel/renewable diesel with petroleum diesel which already contains additives. (Additives may not have been selected for alternate diesel fuel compatibility).

Conditions which Exclude

- Fuel delivered meeting ASTM D975 (ULSD) or ASTM D7467 (B6–B20) specs with no additional aftermarket additive loading.
- Adding additives at proper temperatures and with adequate mixing/dilution.
- Avoiding multiple aftermarket products unless verified by supplier.

Ideal Samples

- Samples of material trapped and concentrated on fuel filter can help identify source.
- Samples of the typical fuel flow can help identify overall concentration of additives in the fuel.
- Samples from tank bottoms may identify any components which have settled due to high density.

Formal Laboratory Tests which can Confirm

- ASTM D2068 – Filter Blocking Tendency (FBT)
- ASTM D3241 – Thermal Stability
- FTIR Spectroscopy – Identifies chemical functional groups in residues
- Compatibility bench tests (supplier-provided)

Field Tests to Confirm

- Clear jar test - fuel may turn hazy after additive addition.
- Filter inspection may reveal sticky or gummy residues inconsistent with wax, rust, or biological material.

Limits / Guidelines

- No ASTM D975 spec limit for additive interactions.
- Control via additive treat rates and compatibility testing.
- Best practice: Additives should be introduced only under OEM/supplier approval and at documented concentrations.

Corrective Measures

- Work with additive suppliers to confirm compatibility before dosing.
- If cross-reaction is suspected: isolate and replace affected fuel.
- Require COA (Certificate of Analysis) from suppliers of treated fuel.
- Implement additive-use SOPs at fueling depots (dose control, single-source supply).

Not Recommended

- Blindly adding aftermarket additives without supplier/OEM approval.
- Using multiple additive packages from different vendors simultaneously.
- Attempting to fix additive reactions with more additives (often worsens precipitation).

Delayed Maintenance

Appearance of a filter which has collapsed due to material build-up from an extremely long service interval.

Delayed Maintenance

When service intervals are exceeded, normal debris accumulation eventually causes restricted flow, high differential pressure, and plugging — even if fuel quality is otherwise acceptable.

Conditions which Generate

- Filter operating hours / lifetime exceeding recommended service intervals for fuel filtration.
- Filters left in service despite increasing differential pressure.
- Deferred servicing during heavy utilization or reduced shop availability.

Conditions which Exclude

- Filters and fuel infrastructure maintained within OEM-recommended service intervals and using correct filter type/micron rating.

Ideal Samples

- Removed filters show excessive debris, collapsed pleats, or bypass channeling.
- Fuel samples from injectors or pump lines show elevated particulates which may indicate collapsed or perforated filters.

Formal Laboratory Tests which can Confirm

- ASTM D6217 – Gravimetric particulate analysis.
- ASTM D2276 – Particulate contamination via membrane.
- Trend analysis on used filters (flow/pressure testing).

Field Tests to Confirm

- Differential pressure gauge across filter shows rising restriction.
- Visual inspection of spent filter shows heavy loading and fouling.
- Increased locomotive fuel consumption or loss of power under load.

Limits / Guidelines

- OEM best practice: Zero visible sediment tolerated.
- ASTM D6217 - 24mg/L maximum particulate.
- ISO 4406 cleanliness typically targeted from ISO 18/16/13 down to 12/9/6 or cleaner for modern diesel systems.

Corrective Measures

- Adhere strictly to OEM filter service schedules (calendar- or usage-based). Monitor differential pressure gauges during runs.
- Maintain inventory of OEM-approved filters (correct micron rating & flow capacity).
- Conduct root cause analysis for rapid filter plugging (fuel contamination vs. deferred maintenance).

Not Recommended

- Extending filter life beyond OEM specs to cut costs (false economy — leads to injector/pump failures).
- Filter plugging will often progress at an exponential rate, so do not expect a filter halfway to a differential pressure cut off at a given in-service time will last that same interval into the future. Often, it may only last ½ or ¼ as long.

Improper Maintenance

Identical fuel filters which would both fit the same application. However, one filter carries a 2 micron filter rating (left) while the other carries a 10 micron rating (right). Using either filter in place of the other could cause maintenance issues due to extremely short lifetime / excessive plugging (2 micron when a 10 micron should be used), or due to allowing large contaminants in the fuel stream (10 micron when a 2 micron should be used).

Improper Maintenance

Installing incorrect components (filter that is too fine or too small) results in rapid particulate loading, causing shortened filter life or immediate plugging.

Conditions which Generate

- Replacement filters with lower capacity or finer-than-specified micron ratings installed (restricts flow, reduces life).
- Improper installation of filters, gaskets, or seals during servicing.

Conditions which Exclude

- Locomotives serviced with OEM-approved filters, correct micron ratings, and properly installed components.

Ideal Samples

- Filters showing uneven loading, collapsed pleats, or torn media due to inferior quality construction.
- Evidence of bypassing — debris downstream of filters (in pump/injector samples).

Formal Laboratory Tests which can Confirm

- ASTM D6217 – Gravimetric particulates (to quantify downstream contamination)
- Filter manufacturer capacity/efficiency testing data (Beta ratio/ISO 16889 multi-pass)

Field Tests to Confirm

- Differential pressure trending inconsistent with OEM expectations (too fast = undersized filters).
- Visual inspection of installed filters for mismatched part numbers or seal integrity.
- Fuel leaks at improperly seated gaskets.

Limits / Guidelines

- Use OEM specified make and model of filter.
- Deviating from OEM recommendations may substantially affect filter life expectations.

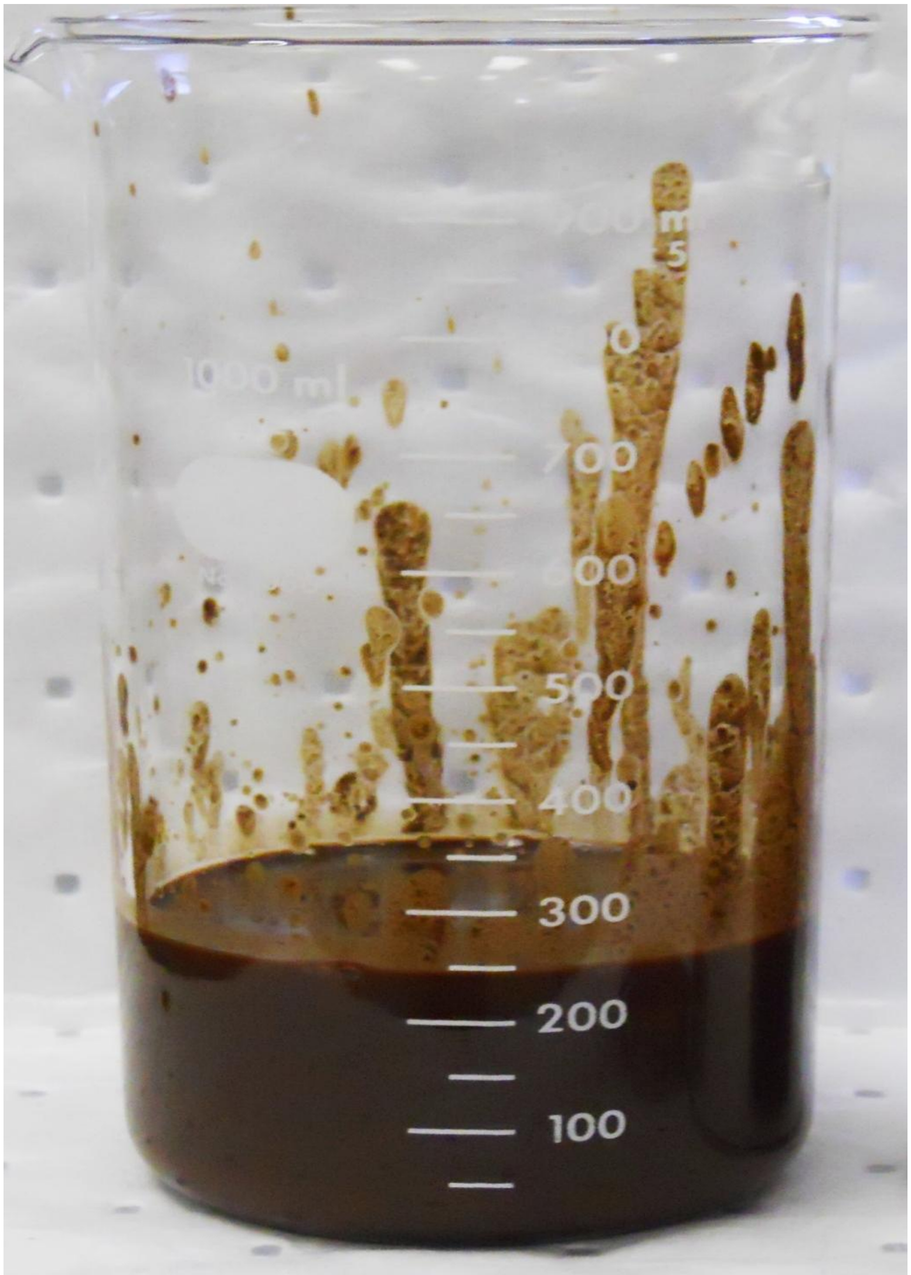
Corrective Measures

- Always use OEM-approved filter part numbers or certified equivalents.
- Train maintenance crews on proper installation torque and gasket material.
- Track filter performance vs. OEM expectations (differential pressure, service life).
- Implement a quality check system for parts sourcing to avoid counterfeit/low-grade filters.

Not Recommended

- Substituting automotive/truck filters for locomotive use. Installing finer-than-specified micron filters to “improve cleanliness” will substantially reduce operating lifetime.
- Conversely, installing coarser-than-specified micron filters to “improve filter lifetime” may result in damage or accelerated wear to fuel system mechanical components.

Fuel Solvency Changes



Sludge disturbed from a fuel tank by a sudden change to high percentage of alternate diesel fuels.

Fuel Solvency Changes

Sudden use of high percentage of biodiesel or renewable diesel fuel in a system which previously used only petroleum diesel. Biodiesel has higher solvency than petroleum diesel, meaning it can dissolve deposits and varnish from the fuel system. Alternatively, renewable diesel has lower solvency that petroleum derived diesel, meaning it can cause precipitation of solids from fuel blends.

Conditions which Generate

- Sudden transition from ULSD to biodiesel blends (B5–B20) or renewable diesel.
- Change in aromatic content — renewable diesel is paraffinic (low solvency), while biodiesel has higher solvency than ULSD.
- Systems with long service history on petroleum diesel containing legacy varnish or deposits.

Conditions which Exclude

- Locomotives with consistent long-term use of stable, single-source fuel.
- Fuel systems proactively cleaned and filtered during transitions.
- Newly installed tanks, hoses, and components without historical varnish buildup.

Ideal Samples

- Filter debris: sticky, dark, resin-like deposits.
- Tank visual inspections: previously stable varnish deposits show signs of dissolution.
- Jar samples: cloudy appearance, fine suspended debris.

Formal Laboratory Tests which can Confirm

- ASTM D7371 or InfraCal Biodiesel Analysis - To confirm biodiesel in fuel
- ASTM D7806 – Biodiesel content in fuel (1–40%)
- ASTM D6866 – Biogenic carbon analysis (renewable/biodiesel)
- ASTM D5186 – Aromatic content determination

Field Tests to Confirm

- Filters plugging shortly after switching to biodiesel/renewable diesel. Increased differential pressure readings without visible rust/sand.
- Brown/black soft, smeary residue on filter pleats that melts or smears with finger pressure.
- Plugging occurs hours or days after switching fuel, especially on first few tank cycles.

Limits / Guidelines

- ASTM D975 (ULSD) and ASTM D7467 (B6–B20 biodiesel blends) specify fuel quality but do not account for solvency transition issues.
- EN 14214 (Europe) enforces stricter biodiesel quality (monoglycerides, sterol glucosides ≤20 ppm).
- OEMs: approve up to B20 biodiesel and 100% renewable diesel (R100) but require that transitions are managed to avoid sudden changes in solvency.

Corrective Measures

- Polish fuel tanks (recirculation + filtration) to strip dissolved deposits before full service.
- Use OEM-approved elastomers (e.g., Viton®) which tolerate solvency changes without swelling/leaks.
- Work with suppliers to ensure biodiesel meets ASTM/EN stability and cold-flow requirements.

Not Recommended

- Rapid switch from 100% ULSD to high-level biodiesel or renewable diesel without system cleaning.
- Making a switch in extremely hot or extremely cold weather. Hot weather may increase the solvency issue and cold weather may mean the filters are already stressed due to fuel cold-flow properties.

Salt Crystals

Calcium chloride salt crystals on a filter pleat.

Salt Crystals

Sodium Chloride, Magnesium Chloride or Calcium Chloride crystals from refinery salt dryer on filter. These salts precipitate as white/opaque crystals that accumulate rapidly on filters and do not dissolve in diesel fuel.

Conditions which Generate

- Refinery salt dryer carryover into diesel fuel.
- Fuel contaminated with seawater or brine during storage/transport (e.g., marine supply depots).
- Moisture ingress + dissolved salts that later crystallize in fuel.

Conditions which Exclude

- Fuel sourced from refineries or terminals with controlled desalter/salt dryer operations and verified salt content.
- Fuel consistently tested and meeting ASTM D975 for corrosion and water specifications.

Ideal Samples

- Filter debris shows crystalline white crystalline deposits (often mistaken for sand).
- Bottom samples may reveal white crystalline deposits.
- Corrosion/rust often present alongside salts.

Formal Laboratory Tests which can Confirm

- ASTM D7111 – Elemental analysis of metals (ICP-OES)
- ASTM E1508 – Elemental determination by EDS
- ASTM D6428 – Determination of chloride content in hydrocarbons

Field Tests to Confirm

- Filter inspection - white (or fuel colored), crystalline material that does not crush like sand but dissolves in water.
- Water-wash test - salt dissolves in water, confirming identity.

Limits / Guidelines

- ASTM D7111 - sodium + potassium combined ≤1 mg/kg (ppm).
- OEM best practice: effectively zero tolerance for salt crystals in delivered locomotive fuel.
- Marine/rail guidelines: chloride levels should be <1 ppm to prevent corrosion and deposits

Corrective Measures

- Isolate and remove contaminated fuel if salts are detected. Flush and clean fuel tanks and replace filters.
- Work with suppliers/refineries to verify salt dryer carryover control.
- Maintain tight controls against seawater ingress during marine transit.
- Use desiccant breathers and tank sealing to minimize salt-laden moisture intrusion.

Not Recommended

- Attempting to dissolve salts with alcohol or water — worsens corrosion and increases water contamination.
- Blending contaminated fuel with clean stocks (salts remain and redistribute).

Asphaltenes

Fuel filter with an accumulation of black, tar-like asphaltenes. The coating may appear like soot or may take on an appearance of 'road tar' with higher concentrations.

Asphaltenes

Asphaltenes are 'tar-like' molecules naturally present in residual amounts in diesel fuels. These molecules can destabilize and precipitate when exposed to incompatible fuel blending, thermal stress, or oxidation conditions.

Conditions which Generate

- Thermal stress, such as high fuel return temperatures in modern injection systems.
- Oxidation during long storage, especially in warm tanks.
- Contact with certain additives (especially overdosed dispersants or incompatible detergents) that disrupt molecular stability.

Conditions which Exclude

- Use of properly blended fuels with stable solvency balance.
- Consistent use of fresh fuel with low storage times and good turnover.
- Systems that maintain cooler return fuel temperatures, reducing thermal cracking or oxidation.

Ideal Samples

- Samples of material trapped and concentrated on fuel filter can help identify source.
- Samples of the typical fuel flow can help identify overall concentration of particulates in the fuel.

Formal Laboratory Tests which can Confirm

- ASTM D7545 – Oxidation Stability
- ASTM D6468 – Thermal Stability
- FTIR Spectroscopy

Field Tests to Confirm

- Jar test - shaking may temporarily suspend particles, but they settle slowly as a fine dark layer.
- Particles do not melt with moderate heat, distinguishing them from wax or monoglycerides.
- Magnet test: particles do not respond (distinguishes from rust).

Limits / Guidelines

- No explicit ASTM D975 limit for asphaltenes, typically controlled indirectly through stability requirements.
- Fuel should pass ASTM D7545 with acceptable induction period.
- ASTM D6468, ≥70% reflectance.

Corrective Measures

- Remove unstable fuel or blend with stable petroleum stocks to dilute asphaltene concentration.
- Use dispersant additives designed for asphaltenes.
- Regularly clean tanks and replace filters to prevent downstream fouling.

Not Recommended

- Attempting to burn through unstable/asphaltenic fuel without treatment can lead to injector fouling and deposits.
- Long-term storage of unstable blends without monitoring stability.
- Using generic cold-flow improvers (ineffective against asphaltenes).

Jar Test

A very basic test using a simple 1-quart Mason-style glass jar (or equivalent) and a flashlight. Obtain fuel samples from the lowest points of the system. (Tank bottom drains, fuel filter drain ports, water separator drains, etc.) Collect and discard any initial water, rust, sediment or other material initially flowing out of the sample port, then sample the representative fuel flow.

Sample should be clean, bright, translucent, displaying only a single layer of fuel and should not display any evidence of cloudiness, floating, settled or suspended solids, or multiple layers which would have indicated water and or biological material present.

Clear, bright, translucent fuel with no evidence of cloudiness, floating, settled or suspended solids, or multiple layers which would have indicated water and or biological material present.

Discussion

Most fuel filter plugging events can be narrowed down into a typical set of categories:

- A mismatch between fuel condition and operating environment (temperature-driven wax or ice).
- Water-driven events (free water, suspended/hazy water) that either plugs directly or enables other mechanisms.
- Biological growth and corrosion products that create sticky, filter-plugging debris.
- Chemistry-driven precipitates (e.g., biodiesel-related components, solvency changes, additive interactions) that form solids or gels.
- Plain contamination (dirt/sand, construction debris, disturbed sediment, salt) that loads filters rapidly.

A practical diagnostic workflow is detailed in the ***"RESTART"*** process:

- **(R) Recognize the issue** - Recognizing a fuel filter plugging issue would ideally start by noticing slight changes in the fuel supply.
- **(E) Expect the issue to continue getting worse** - In most cases a fuel filter plugging issue will only get worse unless prompt corrective action is taken.
- **(S) Sample** - Sampling of the fuel filter itself, fuel contained in the filter housing and the general fuel supply are keys to correct and positive identification of the issue.
- **(T) Test** - Testing helps drill down to the or root cause of the filter plugging issue.
- **(A) Action** - With firm evidence of a root cause based on rigorous and valid testing, the best method to deal with the filter plugging issue can be determined and an action plan can be put in place.
- **(R) Resample / Retest** - With the action plan in place, improvements in fuel quality should be noted. However, it is important to resample and retest the fuel at this point to ensure quality metrics are being met and the previous action has been sufficient to eliminate the original plugging issue.
- **(T) – Train / Learn** from the issue - Once the filter plugging issue has been successfully mitigated, it is important to train and learn from the situation.

Collectively, these findings highlight that filter plugging issues are diverse but diagnosable through a structured approach.

Conclusion and Best Practices

In conclusion, this guide has been set up to help fuel management personnel dealing with a wide range of issues in the modern fuel landscape. Key points are detailed for a wide range of possible filter plugging issues. By acting swiftly and stepping confidently through the RESTART process, clean, filtered fuel flow can be restored promptly.

Best Practices Always Include

- Control water relentlessly: drain tank bottoms and low points, maintain water separators, and prevent humid air exchange (good vents, desiccant breathers where appropriate).
- Manage cold weather proactively: use seasonally appropriate fuel, verify Cloud Point/CFPP margins versus expected ambient minimums, and treat with cold-flow improvers before crystallization begins.
- Keep the system clean after any work: protect open lines, flush/clean after construction or repair, and expect short-term filter loading if sediment is disturbed.
- Treat additives as a system: avoid mixing packages from multiple sources, avoid over-dosing, and document exactly what was added and when.
- Maintain on schedule: correct filter types, correct installation, and service intervals that match real contamination loading - not just calendar time.
- Monitor and trend: differential pressure across filters, water drain volumes, recurring haze, microbial indicators, and supplier/batch changes.

When plugging happens

- Stabilize operations safely: restore flow with proper filter changes and address the obvious (drain water, warm fuel when wax/ice is suspected).
- Isolate the cause before changing multiple variables at once; otherwise, you will not know what fixed it.
- Capture evidence (fuel + deposit) and document conditions at the time of failure; this is what turns a one-off fix into a permanent fix.

Avoid the common self-inflicted mistakes

- Do not bypass or remove filtration to 'get running' - that trades a filter plugging event for injector/pump/engine damage.
- Do not use improvised solvents or additives (e.g. gasoline or methanol) to solve cold-flow problems; they create new risks and often do not work.
- Do not rely on unproven devices (magnetic/electronic anti-gelling gadgets) instead of quality fuel additives from reputable companies, physical water control / water draining and rigorous maintenance discipline.

APPENDIX

Full Title of ASTM Tests Referenced in this Document

Cloud Point Tests
ASTM D2500 - Standard Test Method for Cloud Point of Petroleum Products and Liquid Fuels
ASTM D5773 - Standard Test Method for Cloud Point of Petroleum Products and Liquid Fuels
ASTM D7689 - Standard Test Method for Cloud Point of Petroleum Products and Liquid Fuels (Mini Method)

Cold Filter Plugging Point (CFPP)
ASTM D6371 - Standard Test Method for Cold Filter Plugging Point of Diesel and Heating Fuels

Low-Temperature Flowability / Filterability
ASTM D4539 - Standard Test Method for Filterability of Diesel Fuels by Low-Temperature Flow Test (LTFT)

Water & Sediment Tests
ASTM D2709 - Standard Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge

Karl Fischer (Water Content) Tests
ASTM D6304 - Standard Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration

Visual Appearance / Free Water / Haze / Particulate Tests
ASTM D4176 - Standard Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)

Corrosion / Elemental Composition Tests (EDS)
ASTM E1508 - Standard Guide for Quantitative Analysis by Energy-Dispersive Spectroscopy

Biodiesel Content & Composition Tests
ASTM D7371 - Standard Test Method for Determination of Biodiesel (Fatty Acid Methyl Esters) Content in Diesel Fuel Oil Using Mid-Infrared Spectroscopy (FTIR-ATR-PLS Method)
ASTM D6584 - Standard Test Method for Determination of Total Monoglycerides, Total Diglycerides, Total Triglycerides, and Free and Total Glycerin in B-100 Biodiesel Methyl Esters by Gas Chromatography.
ASTM D7806 - Standard Test Method for Determination of Biodiesel (Fatty Acid Methyl Ester) and Triglyceride Content in Diesel Fuel Oil Using Mid-Infrared Spectroscopy (FTIR Transmission Method)
ASTM D7501 - Standard Test Method for Determination of Fuel Filter Blocking Potential of Biodiesel Fuel Blendstock (B100) by Cold Soak Filtration Test (CSFT)

Renewable / Biogenic Carbon Content
ASTM D6866 - Standard Test Methods for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis

Drag-Reducing Agent (DRA) / Polymer Additive Analysis
ASTM D2068 - Standard Test Method for Filter Blocking Tendency (FBT) of Distillate Fuels
ASTM D5296 - Standard Test Method for Molecular Weight Averages and Molecular Weight Distribution of Polystyrene by High-Performance Size-Exclusion Chromatography
ASTM D7872 - Standard Test Method for Determination of Drag Reducing Agent (DRA) Content in Hydrocarbon Liquids

Particulate Contamination Tests

ASTM D6217 - Standard Test Method for Particulate Contamination in Middle Distillate Fuels by Laboratory Filtration

ASTM D2276 - Standard Test Method for Particulate Contaminant in Aviation Fuel by Line Sampling

Metals / Elemental Analysis

ASTM D5185 - Standard Test Method for Multielement Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)

ASTM D7111 - Standard Test Method for Determination of Trace Elements in Middle Distillate Fuels by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)

Water / Salt / Chlorides / Contamination

ASTM D6428 - Test Method for Total Sulfur in Liquid Aromatic Hydrocarbons and Their Derivatives by Oxidative Combustion and Electrochemical Detection (Withdrawn)

Oxidation / Thermal Stability

ASTM D7545 - Standard Test Method for Oxidation Stability of Middle Distillate Fuels — Rapid Small Scale Oxidation Test (RSSOT)

ASTM D6468 - Standard Test Method for High Temperature Stability of Middle Distillate Fuels

Closing

This is meant to be a 'living document' which will be updated and revised as new changes are introduced and new issues are encountered in the fuel landscape.

Please feel free to send thoughts, suggestions, or contact with additional information at:
https://lmoarail.com/contact-us/

Version	Release Date	Notes / Changes
Version 1	June 2026	Original Version
Version 2	TBD	

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