Aircraft Diesel Exhaust Fluid Contamination Working Group

A COLLABORATIVE INDUSTRY REPORT ON THE HAZARD OF DIESEL EXHAUST FLUID CONTAMINATION OF AIRCRAFT FUEL

JUNE 11, 2019

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EXECUTIVE SUMMARY

June 11, 2019

Our organizations are calling on all aviation stakeholders to familiarize themselves with the risk of Diesel Exhaust Fluid (DEF) contamination and the events that have occurred to date; to immediately adopt this report's short-term mitigation recommendations; and to partner in our efforts to ensure that no further aircraft fuel supplies are contaminated with DEF through continued vigilance, training, monitoring, and checking. As future mitigations and technologies are identified, we anticipate swift incorporation, at that time.

Several significant inflight emergencies related to engine operability issues and failure due to fuel contamination prompted an extensive safety and technical investigation with consideration of more effective mitigations. Separate events in November 2017, August 2018, and May 2019 in which DEF contaminated jet fuel uplifted to aircraft from aircraft refueling trucks at fixed base operators (FBOs) in Omaha, Nebraska; Opa Locka, Florida; and Punta Gorda, Florida have renewed the aviation industry's focus on fuel contamination.

This resource, developed by a working group of industry and FAA participants, has studied the factors around these DEF aircraft fuel contamination events; conducted a safety risk assessment of DEF fuel contamination; developed mitigation strategies for aircraft operators, FBOs, and fuel suppliers; and has produced this report, all in an effort to inform the industry of the events and factors around which these contaminations took place, and request the immediate adoption of the identified recommendations in order to prevent such events from recurring.

The risk associated with diesel exhaust fluid fuel contamination of aircraft fuel is high. The crystallization of DEF in the aircraft's fuel supply can quickly cause engine operability issues and failure. Luckily, the aircraft which have experienced anomalous engine behavior and failures have successfully diverted to a landing facility. Most recently, a Citation landed with both engines not producing thrust. Several factors were identified that contributed to co-mingling of fluids and/or inappropriate introduction of DEF into refueling truck anti-ice inhibitor tanks.

We thank you, in advance, for your help in this important effort.

Sincerely,

Mark Baker
President and CEO
Aircraft Owners and Pilots Association

Pete Bunce
President and CEO
General Aviation Manufacturers Association

Gary Dempsey
President and CEO
National Air Transportation Association

Ed Bolen
President and CEO
National Business Aviation Association

INTRODUCTION

Aviation fuel is critical to aviation safety, and the potential for contamination of that fuel is a hazard that the industry must mitigate. This resource aims to inform the aviation industry of three aircraft fuel contamination events that occurred in November 2017 at Omaha, Nebraska, August 2018 at Opa Locka, Florida and May 2019 at Punta Gorda, Florida, where diesel exhaust fluid (DEF) was identified as the contaminant. It details how those events transpired, offers a safety analysis of those events and the risk that DEF contamination poses to safety, and proposes recommendations for aircraft operators, fixed base operators (FBOs) and fuel suppliers to adopt to reduce the likelihood of another inadvertent DEF fuel contamination event.

WHAT IS DIESEL EXHAUST FLUID?

As part of the new Clean Air Act (CAA) of 1990, the Environmental Protection Agency (EPA) has progressively mandated stronger emission control standards for vehicle engines to curb air pollution. Nitrogen oxides (NOx), sulfur dioxide, hydrocarbons, particulate matter and carbon monoxide (CO2) emissions from vehicles cause health and environmental problems. In diesel engines, NOx emissions can be a major contributor to smog formation, acid rain and ground level ozone pollution. NOx in diesel engine emissions has been targeted for drastic reduction by the EPA. “Clean Diesel” technology has been developed by diesel engine manufacturers in response to EPA regulations. In 2007, the EPA required that all new on-road heavy duty vehicles manufactured from 2010 must meet the 0.2 grams of NOx and 0.01 grams of Particulate Matter per brake horsepower-hour. Light duty vehicles were required to meet this mandate in 2014. To meet these standards, vehicle and engine manufacturers have developed aftertreatment technologies such as Diesel Particulate Filters (DPF) and Selective Catalytic Reduction (SCR).

SCR has been used for years at many coal-fired power generation plants to reduce NOx emissions, often referred to as “scrubbing” of the power plant exhaust. In diesel vehicles, SCR reduces NOx emissions by injecting DEF directly into a catalytic convertor in the exhaust system. The exhaust heat helps to break down DEF into ammonia, which in the presence of the catalyst, reacts with the exhaust NOx to neutralize it into harmless nitrogen gas and water.

DEF is a nontoxic, nonhazardous and colorless aqueous solution of 32.5% automotive grade Urea in deionized (purified) water. In other parts of the world, DEF is known as Aqueous Urea Solution (AUS 32). In Europe, a common brand of AUS 32 is AdBlue®. The AdBlue® brand is trademarked by the German Association of the Automotive Industry (VDA) and is licensed to manufacturers who meet their strict guidelines. Because of its world-wide popularity, the word AdBlue has become nearly a generic term for DEF and AUS 32.

The DEF producers are required to manufacture to strict ISO-22241 standards and certified by the American Petroleum Institute (API). Purity and correct concentration are critical for the performance of the SCR system and the efficacy of the NOx reduction process. As such, the DEF storage and handling equipment must also be manufactured to maintain its purity. Storage should be between 12 to 86 F for the stability of DEF, which generally has a one (1) year shelf-life. Dosage rates depend on the vehicle and engine manufacturers but can generally be 2 - 6% rate of diesel consumption.

The EPA has adopted multiple tiers of emission standards. The EPA mandated Tier 4 emissions standards for off-road diesel engines starting in 2014. This applies to airport vehicles which are now equipped with SCR systems and therefore require DEF.

DIESEL EXHAUST FLUID CONTAMINATION EVENTS

DEF is not a fuel additive, rather it is stored in a separate tank on vehicles where an SCR system has been installed and is used to “treat” the exhaust of those engines. **When DEF is mixed with diesel or jet fuel, it forms crystalline deposits in the fuel. These crystalline deposits can clog fuel filters and other fuel system components and have the potential to corrode or degrade numerous materials commonly used in aviation applications, with potentially catastrophic consequences.**

In each of the three events, DEF was confused with Fuel System Icing Inhibitor (FSII), which is more commonly known by brand names “PRIST,” “DICE,” and also referred to as DiEGME. FSII is used to address the potential for freezing of any water within jet fuel when the aircraft is at altitude. Its properties also make it ideal for the prevention of microbial growth that can occur in aircraft fuel tanks.

Eppley Airfield (OMA) DEF Contamination Event

An investigation of this event suggests that on November 17, 2017 at 2037 the FSII container on truck #1 was inadvertently topped off with roughly 3.5 gallons of DEF.

On November 18, 2017 at roughly 1700 a discrepancy was identified by an operator that was fueled on November 17. Immediately after getting notice, the FBO performed all industry quality control checks on the jet fuel trucks and the fuel farm supply with the oversight of the fuel supplier. All fuel test samples did not reveal any discrepancies and conformed to ATA 103 standards. As a result, the supplier along with the FBO agreed to return the trucks to normal operation.

On November 19, 2017 at 1859 the FSII container was removed from truck #1 and replaced with a fresh undiluted FSII container.

The investigation further suggests that on November 19, 2017 at 2035, the FSII container previously removed from truck #1, which was roughly 1/3 full and contained roughly 60% DEF, was topped off with roughly 3.5 gallons of FSII and installed on truck #2.

On November 20, 2017 at roughly 1700 another operator identified a fueling discrepancy. At roughly 1900 all the fuel was removed from the jet fuel trucks and replaced with clean supply fuel. Tests were completed and came back clean and dry and the trucks were returned to service.

On November 20, 2017 at 2100, out of an abundance of caution and without identifying the FSII container as the culprit, all FSII containers were emptied and were refilled with clean FSII. New replacement FSII tanks were ordered and installed on November 27.

On November 30, 2017 the FBO was advised by the supplier that urea was found in a fuel sample, however the exact source of the urea was still being investigated. After receiving notification, the FBO began immediate identification and notification of all operators fueled between November 17 and November 21.

In this event, 7 aircraft uplifted jet fuel contaminated with DEF, and an additional 6 aircraft were uplifted with jet fuel using refueling equipment that was exposed to DEF. There were also several military aircraft impacted with this event.

Miami-Opa Locka Executive Airport (OPF) DEF Contamination Event

On August 14, 2018, a Dassault Falcon 900EX was forced to return to OPF after the flight crew received multiple clogged fuel filter warnings on departure, followed by failure of the trijet’s number 2 engine. The aircraft returned safely to OPF, but not before a second engine became unresponsive to throttle inputs.

Subsequent testing revealed fuel contamination consistent with the presence of DEF. The FBO traced the issue back to a FSII tank that had been removed from a fuel truck for repair, then accidentally filled with DEF for leak checks prior to reinstallation.

The FBO had procedures in place to avoid cross-contamination, including the fuel farm DEF hose being too short to reach the FSII tank, however, those procedures were contingent on the tank not leaving the truck. The DEF tank has since been relocated away from the fuel farm.

In this event, 5 aircraft uplifted jet fuel contaminated with DEF, and an additional 9 aircraft were uplifted with jet fuel using refueling equipment that was exposed to DEF

Punta Gorda (PGD) DEF Contamination Event

Two Citation 550s, both operated by the same Part 135 operator received 480 gallons and 440 gallons at Punta Gorda Airport (PGD) on the morning of May 9, 2019. One other aircraft was fueled that morning with FSII from the same truck, an Eclipse jet. It has been confirmed that a pail of approximately 2.5 gallons of unmarked DEF was mixed with a container of FSII prior to servicing the FSII reservoir on the refueler truck.

Both aircraft flew from PGD to Naples Airport (APF) that morning, and received another 195 gallons and 168 gallons respectively, picked up their passengers and departed on separate flights to different destinations. One aircraft was headed to Chicago Executive Airport (PWK) and the other aircraft was headed to Niagara Falls International Airport (IAG).

It was on those flights that the Citation en route to IAG experienced an engine flameout at 35,000 feet, descended, then at 8,000 feet on approach to Savannah/Hilton Head Airport (SAV), experienced the second engine flameout, then landed without either engine, without damage or injuries. The other Citation en route to PWK experienced an engine flameout at 36,000 feet, descended and landed with one engine operative at Louisville International Airport (SDF) without damage or injuries.

FBO personnel at APF placed their refueler and storage tank out of service until it was confirmed their fuel was not contaminated with DEF. There have been no reports of operational or maintenance issues with the Eclipse jet, but that investigation is continuing.

DIESEL EXHAUST FLUID CONTAMINATION SAFETY ANALYSIS

Following these notable DEF contamination events that occurred months apart and at multiple locations, it was apparent that a safety analysis was necessary to more fully probe into root cause(s) and provide effective mitigations. As opposed to a traditional probability-based risk assessment, the DEF working group employed a human factors taxonomy to go beyond ‘how’ the events happened, and drive to the ‘why.’ The Human Factors Analysis and Classification System (HFACS) framework was the chosen framework.[1]

HFACS Level 1 assesses the *Unsafe Act* and is divided into two categories: errors and violations. Based on the investigation information provided from the DEF contamination events, it appeared that both were errors. With no written policy or guidance on storage and handling of DEF, line operators mistakenly introduced DEF into FSII containers that directly feed to jet fuel supply. Because the DEF container markings were ambiguous, line operators can perceive (incorrectly) that they are handling FSII. In summary, HFACS *Unsafe Act* was classified a *Perceptual Error*.

HFACS Level 2 assesses the *Preconditions for the Unsafe Act* and is divided into three categories: environmental factors, condition of operator, and personnel factors. The investigations revealed that line personnel were under perceived time pressure, and due co-mingling of fluid containers in nearby storage area, resulted in inadvertent selection of DEF instead of FSII. The operational environment that is common on FBO flight lines requires rapid access to servicing additives for both aircraft and ground support equipment. This can create an environment for errors, particularly if there are no controls in place to mitigate confusion or inadvertent container selection. In summary, HFACS *Precondition for the Unsafe Act* was classified as *Physical Environment*.

HFACS Level 3 assesses the *Unsafe Supervision* and is divided into four categories: inadequate supervision, planned inappropriate operation, failure to correct known problem, and supervisory violation. The investigations didn't uncover a prior recognition among supervisory personnel that there was a latent threat by having fluids stored in or near the flight line and could be easily confused. However, supervisors are expected to be proactive in identifying potential hazards and accommodating the "as-is" environment in establishing policies and procedures, as well as the operational safety oversight. Anecdotal evidence suggests that FBO line service personnel experience a high turnover rate, exacerbating the challenges of training, as well as promotion of active hazard identification and risk controlling. In summary, HFACS *Unsafe Supervision* was classified *as Inadequate Supervision*.

HFACS Level 4 assesses *Organizational Influences* and is divided into three categories: Resource Management, Organizational Climate, and Operational Process. Investigative results noted variance across FBOs in their process and procedures for storage and handling of additives and replacement fluids. Lack of operational procedures, insufficient control/oversight and training deficiencies were prominent in the findings which can severely limit effective employee active risk control. In summary, HFACS *Organizational Influences* was classified as *Operational Process*.

[1]For more information on HFACS see: https://www.skybrary.aero/bookshelf/books/1481.pdf

DIESEL EXHAUST FLUID CONTAMINATION MITIGATION STRATEGIES

When reviewing possible actions to reduce the risk/impact of DEF contamination of aviation fuel, mitigations can be broadly categorized as preventative, detection and response. Mitigations can further be understood by the entity that deploys them, such as an FBO or other fuel handler, aircraft operator, terminal operator or even an airport. As with many other safety initiatives within our industry, the most effective results are achieved through a comprehensive approach that pairs/incorporates cooperation between multiple lines of business (i.e. FBO & aircraft operator) with a blended mitigation deployment (not focusing on only one mitigation category). This section is not intended to be a comprehensive set of mitigations providing a solution to the issue of DEF contamination of aviation fuel, rather it outlines existing and possible mitigations that should be considered and possibly deployed through cooperative industry and FAA action.

Prevention

The prevention of DEF contamination of aviation fuel requires organizational leadership and active risk controls. However, based upon recent cases of contamination, and the high risk of serious impacts when contamination occurs, a review of the contamination prevention is in order. Fuel contamination prevention can include three overlapping components, education/training, refuel system design and fuel handling policy and process. Applied specifically to DEF contamination, prevention includes:

- Education & Training
    - FBO Leadership
    - FBO Refueling Staff
    - FBO Ground Support Equipment (GSE)/Facility Maintenance Staff
    - Terminal Employees

- Refueling System Design
    - Container Design & Marking
    - FSII Selective Fill Port
    - Fluid and Chemical Storage
    -
- Fuel Handling Policy & Process
    - Formalization of FSII and DEF Handling Processes

One preventative process that may be overlooked is communications and awareness. Following the recent DEF contamination incidents, multiple industry associations and organizations began communicating with their membership, and customer and vendor base regarding this emergent risk. However, DEF contamination events continue to occur. The primary obstacle of communication is creating both awareness and relevance. Industry front line employees may not be in tune with current industry news sources. Industry and FAA stakeholders must continue to work together to create awareness and relevance throughout all constituencies.

The prevention of DEF contamination of aviation fuel is a vital component in mitigating risk, but it cannot be the only mitigation. Contamination events will occur and with the associated high impact (likely inflight engine shutdown) industry should consider the additional mitigation layer of contamination detection.

Contamination Detection

When aviation fuel is contaminated, regardless of the type of contaminate, it is vital that that contamination is detected prior to that fuel being delivered to an aircraft and, at a minimum, before an aircraft refueled with the affected fuel departs. Detection provides an additional layer of protection so that even if fuel is contaminated, the worst of the impacts (possible aircraft incident) is avoided.

The challenge with detecting DEF is that it is a clear liquid and the primary contamination pathway involves accidental mixing with or replacement of FSII, another clear liquid. Diesel Exhaust Fluid is soluble in FSII, and there will be no phase separation to visually detect water. It is also not immediately visible when sumping a fuel tank. Currently, there is no available field test that can detect the injection of DEF into aviation fuel. FBO staff and aircraft operators cannot visually, or chemically (using current field methods) [1] detect that a contamination event has occurred. This situation places the full burden of risk mitigation upon initial contamination prevention.

Following recent DEF contamination events, key equipment manufacturers and other organizations began searching for new detection methods and discovered that electrical conductivity shows promise as a tool for identifying the presence of DEF contamination of FSII supply. Work continues on developing a field detection system utilizing this property.

In addition to detecting actual DEF contamination, there may be a possibility of identifying instances of contamination through reconciliation of FSII & DEF transfer logs and FSII & DEF usage. Industry should consider periodic reconciliation process that may provide an additional layer of protection.

Response to a Contamination Event

Even with intense coordinated industry efforts to prevent and detect contamination, FBOs, airports and aircraft operators must be prepared to respond to a DEF contamination event in a manner that minimizes risks. FBOs and aircraft operators should develop and implement emergency response plans that address the specific issue related to DEF contamination.

[1]Current field tests include Milipore Filtration, Visual Sample Evaluation, differential pressure monitoring, water detection kit or paste, B2 Test (FSII Concentration) and API Gravity

SHORT AND LONG-TERM RECOMMENDATIONS

AIRCRAFT OPERATORS

SHORT-TERM

Communication – Talk with your fuel providers and ask if they use DEF in ground equipment. If so, inquire about procedures to confirm correct additives are used for jet fuel. This should include separate storage, clear labeling, confirmation of correct additives at the time of insertion, and training for personnel.

Flight Planning – Plan ahead. Call the FBOs that you can use for your itinerary. Question them on the use of DEF and implementation of procedures and training on DEF handling. Talk to line managers, FBO managers, etc. to get the best information. This may be done through a joint effort between your dispatch department and the assigned flight crew. Remember, <u>when you fail to plan you effectively plan to fail.</u>

If you encounter or suspect any DEF contamination or inadequate controls, notify the Fixed Base Operator management where fuel was obtained as soon as possible. Notify your management as part of your Safety Management System (SMS) practices. Document the incident and report it to the local FAA FSDO office immediately. **DO NOT FLY if you suspect fuel contamination may have taken place!**

Proper Awareness, Training, and Reaction – If you get **<u>any</u>** indications of fuel filter clogs or fuel filter bypass, engine spool-back, partial/erratic power, or complete failure due to turbine flameout, be cognizant of the potential for DEF contamination. **If on the ground, do not take-off**. However, these indications will likely not manifest until later stages of the climb segment and possibly not until the cruise segment. **Expect additional filters and engine(s) to follow within a short amount of time. Conserve altitude and turn toward an airport without delay**. **Expect all engines to fail. Plan accordingly.** Do not hesitate to declare an emergency. Follow emergency checklist procedures for engine failure and **<u>realize</u>, <u>if DEF contamination is the cause</u>, that successful restart is very unlikely.** Note, this may also affect APUs and may lead to a significantly exacerbated emergency with added hydraulic system and electrical power management considerations.

LONG-TERM

Pre-flight procedures – There are currently no pre-flight procedures that pilots can use to identify the presence of DEF in jet fuel. If one was to be developed, encourage quick adoption and wide-spread use.

On aircraft fuel monitors – If, despite all of the other mitigations and checks, DEF contaminated fuel was to be onboarded, we are hopeful that technology will be in place to identify the contaminated fuel so an operator can be aware, prior to takeoff.

FIXED BASED OPERATORS

SHORT-TERM

Training - FBOs should immediately adopt the recommendations contained in NATA's Safety 1st Operational Best Practice 36 – DEF Handling and Contamination Prevention (OBP 36) and implement the NATA Safety 1st DEF Contamination Prevention training as part of their regular initial and recurrent training. This training is offered free of charge. Information on accessing OBP 36 and the DEF training can be found in appendix D - NATA Critical Alert – DEF Contamination.

Education – All FBO staff should receive initial training on the importance of proper identification and use of DEF and FSII. This training should include the proper storage locations, labeling, use and handling procedures for DEF and FSII as well as the possible consequences of accidental contamination of aviation fuel with DEF. Such training should be documented and retained in an employee's training file.

Storage of DEF & FSII – DEF and FSII should be stored in different locations and access limited to authorized and trained individuals. Further, a double-check / verification system should be implemented to further reduce the risk of accidental DEF use in FSII systems.

Limiting DEF inventory – FBOs should minimize to the extent practicable inventory of DEF at airport facilities. DEF refills can be planned by monitoring in-truck DEF gauges. DEF can then be procured and dispensed under supervision on an "as-needed" basis. **Stockpiling inventory DEF is not recommended.**

Labels – Storage of DEF and FSII should be in the original clearly marked containers. Should either fluid need to be stored in a secondary container such container should be clearly and conspicuously marked (staff should receive training on marking of secondary containers if used). Mobile refueler FSII tanks should be clearly marked (see Appendix B).

Different size containers – FBOs should purchase DEF and FSII in different sized containers (i.e. 2.5 gal DEF container & 55 gal drum FSII) to reduce the risk of confusion.

Handling Procedures – All transfers of DEF and FSII from storage to use or between storage containers should be performed by authorized and trained personnel and logged appropriately.

LONG-TERM

Education – FBOs should incorporate DEF and FSII training into their annual training program as well as develop a process that ensures that changes to handling procedures (i.e. storage locations, container sizes or marking) are properly communicated to all staff.

Equipment – FBOs may want to consider the use of ground equipment that does not require DEF, where available. Additional system design factors should be considered to reduce the risk of accidental contamination of mobile refuel FSII tanks (use of "preblended' fuel, injection of FSII at a single location such as fuel farm, etc.).

Quality checks and oversight – Close supervision should be the order of the day when servicing FSII and/or DEF containers. Only trained staff should be authorized to complete these tasks and fluids should be under "lock-and-key" and "sign-out" procedures.

System monitoring/detection systems – FBO should talk with their mobile refueler provider and fueling equipment suppliers about the possibility of incorporating new monitoring and detection technologies (when available) to reduce the risk of contamination.

FUEL SUPPLIERS

SHORT-TERM

Awareness and Outreach – Fuel suppliers are well positioned to facilitate communication with FBOs and other refueling agents on the importance and methods of preventing DEF contamination.

Education and Training – Fuel suppliers should promote awareness with vendors and contractors that inject FSII (i.e. terminals and over-the-road haulers) regarding the importance of training on DEF contamination and procedures to prevent contamination.

Labeling – Fuel suppliers that lease mobile refuelers should review their truck fleet to assure proper labeling of FSII tanks on mobile refuelers. Suppliers may want to consider modification to leasing processes to include warnings and industry recommendations on preventing DEF contamination.

LONG-TERM

Premixed Fuel – Fuel suppliers may want to engage in discussions with terminal operators and over the road haulers that inject FSII for delivering "premixed" load of jet fuel to FBOs to assure that effective policies, procedures and training are in place to reduce the risk of contamination through the injection process.

GENERAL

SHORT-TERM

Industry Associations – Continued cooperation in creating awareness of DEF contamination issues and mitigations will assist in reducing the risk of future events. Additionally, facilitating awareness of new technologies and processes to prevent contamination is vital.

EPA exemption – Industry should request an emergency exemption from the rules requiring DEF in on-airport equipment from the EPA.

LONG-TERM

New technologies/vehicles – Continued industry discussions of refueling processes and equipment could identify additional options for preventing future contamination events.

DEF Dyeing – ASTM International Subcommittee D15.25 on Diesel Exhaust Fluid should initiate an activity to incorporate a unique and distinguishable dye into the specification of DEF. By doing so, a further layer of safety will allow line personnel to quickly and visually identify DEF and effectively differentiate it between other fluids.

SUMMARY

The risk of another inadvertent DEF contamination event is too great to not take a concerted, aggressive, and multi-pronged, coordinated approach to prevent another occurrence.

This report, with its safety analysis, mitigation strategies for (1) aircraft operators, (2) Fixed Based Operators, and (3) fuel suppliers, coupled with recommendations for both short and long-term actions represents a good first step but most certainly not the last. The working group members and broader community must and will remain vigilant in monitoring the entire system, reinforcing where needed, and act quickly, if another event unfortunately occurs.

With newer vehicles coming online, replacing older equipment, the risk of another contamination event will only increase if no mitigations are in place. With that recognition, it is our strong recommendation for all stakeholders to review this report and use it to review their particular segment of the overall system and make immediate and appropriate changes, once identified, and continually monitor, check, and re-check to ensure the proper processes and procedures are, and remain, in place.

RESOURCES

Environmental Protection Agency (EPA)

Final Rule - Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements

Ref#: AMS-FRL-6923-7; RIN 2060-AI69
Fed. Reg. Volume: 66, No. 12 Thursday, Jan 18, 2001
Publication Date: Jan 18, 2001
Effective Date: March 9, 2001
Compliance Date: Heavy Duty Vehicles Model Year 2007 and newer

Summary: The pollution emitted by diesel engines contributes greatly to our nation's continuing air quality problems. Even with more stringent heavy-duty highway engine standards set to take effect in 2004, these engines will continue to emit large amounts of nitrogen oxides and particulate matter, both of which contribute to serious public health problems in the United States. These problems include premature mortality, aggravation of respiratory and cardiovascular disease, aggravation of existing asthma, acute respiratory symptoms, chronic bronchitis, and decreased lung function. Numerous studies also link diesel exhaust to increased incidence of lung cancer. We believe that diesel exhaust is likely to be carcinogenic to humans by inhalation and that this cancer hazard exists for occupational and environmental levels of exposure.

We are establishing a comprehensive national control program that will regulate the heavy-duty vehicle and its fuel as a single system. As part of this program, new emission standards will begin to take effect in model year 2007, and will apply to heavy-duty highway engines and vehicles. These standards are based on the use of high-efficiency catalytic exhaust emission control devices or comparably effective advanced technologies. Because these devices are damaged by sulfur, we are also reducing the level of sulfur in highway diesel fuel significantly by mid-2006. The program provides substantial flexibility for refiners, especially small refiners, and for manufacturers of engines and vehicles. These options will ensure that there is widespread availability and supply of the low sulfur diesel fuel from the very beginning of the program, and will provide engine manufacturers with the lead time needed to efficiently phase-in the exhaust emission control technology that will be used to achieve the emissions benefits of the new standards.

We estimate that heavy-duty trucks and buses today account for about one third of nitrogen oxides emissions and one-quarter of particulate matter emissions from mobile sources. In some urban areas, the contribution is even greater. This program will reduce particulate matter and oxides of nitrogen emissions from heavy duty engines by 90 percent and 95 percent below current standard levels, respectively. In order to meet these more stringent standards for diesel engines, the program calls for a 97 percent reduction in the sulfur content of diesel fuel. As a result, diesel vehicles will achieve gasoline-like exhaust emission levels. We are also finalizing more stringent standards for heavy-duty gasoline vehicles, based in part on the use of the low sulfur gasoline that will be available when the standards go into effect.

The clean air impact of this program will be dramatic when fully implemented. By 2030, this program will reduce annual emissions of nitrogen oxides, nonmethane hydrocarbons, and particulate matter by a projected 2.6 million, 115,000 and 109,000 tons, respectively. We project that these reductions and the resulting significant environmental benefits of this program will come at an average cost increase of about $2,000 to $3,200 per new vehicle in the near term and about $1,200 to $1,900 per new vehicle in the long term, depending on the vehicle size. In comparison, new vehicle prices today can range well over $100,000 for larger heavy-duty vehicles. We estimate that when fully implemented the sulfur reduction requirement will increase the cost of producing and distributing diesel fuel by about five cents per gallon.

Final Rule - Emergency Vehicle Rule—SCR Maintenance and Regulatory Flexibility for Nonroad Equipment

Ref#: EPA–HQ–OAR–2011–1032; FRL–9914–63– OAR RIN 2060–AR46
Publication Date: Aug. 8, 2014
Effective Date: Sept. 8, 2014

Summary: This rule consists of three parts.
First, the Environmental Protection Agency (EPA) is adopting minimum maintenance intervals for replenishment of consumable chemical reductant (commonly known as diesel exhaust fluid, or DEF) in connection with the use of selective catalytic reduction (SCR) technologies.
Second, EPA is adopting provisions allowing manufacturers of nonroad engines to give operators the means to obtain short term relief from emission controls while operating in emergency situations, such as those where operation of a nonroad engine or equipment is needed to protect human life, and where obtaining short-term relief from emission controls enables such operation.
Third, EPA is adopting minor revisions to the direct final rule for emergency vehicles that became effective August 7, 2012, in response to comments received on the parallel Notice of Proposed Rulemaking.

Example of where EPA has done its due diligence and works with FAA to address possible contamination issues with nonroad vehicles to ensure aircraft safety is not compromised.

Control of Emissions of Air Pollution From Nonroad Diesel Engines and Fuel

Ref#: OAR-2003-0012; FRL-7662-4; RIN 2060-AK27
Federal Register: Vol. 69, No. 124 Tuesday, June 29, 2004
Publication Date: June 29, 2004
Effective Date: Aug. 30, 2004

Summary (of aviation impact): EPA will continue to work with other federal agencies, including FAA and DoD, and to follow ongoing research and studies regarding the effect of dyes and markers on jet fuel, particularly potential contamination that could have an adverse impact on the safe operation of aircraft.

Federal Aviation Administration Regulations

FAA regulations currently do not directly apply to airport refueling operations. The regulations are applied indirectly via engine and aircraft designers/manufacturers, aircraft operators such as airlines and charter operators, and airport fire/hazardous material regulations.

Regulations Applicable to Engine/Aircraft Designers/Manufacturers.

- These regulations require the aircraft designer to specify the fuel and fuel properties that must be used with the aircraft.

<u>14 CFR Part 33: Engines</u>

§33.7: Engine ratings and operating limitations.
(a) Engine ratings and operating limitations are established by the Administrator and included in the engine certificate data sheet specified in Sec. 21.41 of this chapter, including ratings and limitations based on the operating conditions and information specified in this section, as applicable, and any other information found necessary for safe operation of the engine.
(b) For reciprocating engines, ratings and operating limitations are established relating to the following:

...
(2) Fuel grade or specification.

…
(c) For turbine engines, ratings and operating limitations are established relating to the following:

…
(2) Fuel designation or specification.

<u>14 CFR Part 23: Small airplanes</u>

§23.2620: Airplane flight manual.
The applicant must provide an Airplane Flight Manual that must be delivered with each airplane.
(a) The Airplane Flight Manual must contain the following information—

(1) Airplane operating limitations;

<u>14 CFR Part 25: Large airplanes</u>

§25.1521: Powerplant limitations.
(a) General. The powerplant limitations prescribed in this section must be established so that they do not exceed the corresponding limits for which the engines or propellers are type certificated and do not exceed the values on which compliance with any other requirement of this part is based.
(b) Reciprocating engine installations. Operating limitations relating to the following must be established for reciprocating engine installations:

…
(2) Fuel grade or specification.
…
(c) Turbine engine installations. Operating limitations relating to the following must be established for turbine engine installations:
…
(2) Fuel designation or specification.

<u>14 CFR Part 27: Small helicopters</u>

§27.1521: Powerplant limitations.
(a) General. The powerplant limitations prescribed in this section must be established so that they do not exceed the corresponding limits for which the engines are type certificated.
…
(d) Fuel grade or designation. The minimum fuel grade (for reciprocating engines), or fuel designation (for turbine engines), must be established so that it is not less than that required for the operation of the engines within the limitations in paragraphs (b) and (c) of this section

<u>14 CFR Part 29: Large helicopters</u>

§29.1521: Powerplant limitations.
(a) General. The powerplant limitations prescribed in this section must be established so that they do not exceed the corresponding limits for which the engines are type certificated.
…
(d) Fuel grade or designation. The minimum fuel grade (for reciprocating engines) or fuel designation (for turbine engines) must be established so that it is not less than that required for the operation of the engines within the limitations in paragraphs (b) and (c) of this section.

Regulations Applicable to Aircraft Operators.

- These regulations require aircraft operators to only use the fuel, or a fuel meeting the properties, specified by the aircraft and engine designers.

<u>14 CFR Part 91: All airplane operations</u>

§91.9: Civil aircraft flight manual, marking, and placard requirements.
(a) Except as provided in paragraph (d) of this section, no person may operate a civil aircraft without complying with the operating limitations specified in the approved Airplane or Rotorcraft Flight Manual, markings, and placards, or as otherwise prescribed by the certificating authority of the country of registry.

14 CFR Part 5: Safety Management Systems (for airline operators)

§5.51: Applicability.
A certificate holder must apply safety risk management to the following:
(a) Implementation of new systems.
(b) Revision of existing systems.
(c) Development of operational procedures.
(d) Identification of hazards or ineffective risk controls through the safety assurance processes in subpart D of this part.

§5.53: System analysis and hazard identification.
(a) When applying safety risk management, the certificate holder must analyze the systems identified in § 5.51. Those system analyses must be used to identify hazards under paragraph (c) of this section, and in developing and implementing risk controls related to the system under § 5.55(c).
(b) In conducting the system analysis, the following information must be considered:
- (1) Function and purpose of the system.
- (2) The system's operating environment.
- (3) An outline of the system's processes and procedures.
- (4) The personnel, equipment, and facilities necessary for operation of the system.

(c) The certificate holder must develop and maintain processes to identify hazards within the context of the system analysis.

§5.55: Safety risk assessment and control.
(a) The certificate holder must develop and maintain processes to analyze safety risk associated with the hazards identified in § 5.53(c).
(b) The certificate holder must define a process for conducting risk assessment that allows for the determination of acceptable safety risk.
(c) The certificate holder must develop and maintain processes to develop safety risk controls that are necessary as a result of the safety risk assessment process under paragraph (b) of this section.
(d) The certificate holder must evaluate whether the risk will be acceptable with the proposed safety risk control applied, before the safety risk control is implemented.

14 CFR Part 121: Airline operations

§121.105: Servicing and maintenance facilities.
Each certificate holder conducting domestic or flag operations must show that competent personnel and adequate facilities and equipment (including spare parts, supplies, and materials) are available at such points along the certificate holder's route as are necessary for the proper servicing, maintenance, and preventive maintenance of airplanes and auxiliary equipment.

§121.123: Servicing maintenance facilities.
Each certificate holder conducting supplemental operations must show that competent personnel and adequate facilities and equipment (including spare parts, supplies, and materials) are available for the proper servicing, maintenance, and preventive maintenance of aircraft and auxiliary equipment.

§121.135: Manual contents.
…
(b) The manual may be in two or more separate parts, containing together all of the following information, but each part must contain that part of the information that is appropriate for each group of personnel:

> …
> (19) Procedures for refueling aircraft, eliminating fuel contamination, protection from fire (including electrostatic protection), and supervising and protecting passengers during refueling.

<u>14 CFR Part 125: Utility, air cargo, other large airplane operations</u>

§125.31: Contents of certificate and operations specifications.
…
(b) The operations specifications issued under this part contain the following:

> …
> (6) Any other item that the Administrator determines is necessary to cover a particular situation.

<u>14 CFR Part 135: Commuter, on-demand charter operations</u>

§135.23: Manual contents.
Each manual shall have the date of the last revision on each revised page. The manual must include--
…
(j) Procedures for refueling aircraft, eliminating fuel contamination, protecting from fire (including electrostatic protection), and supervising and protecting passengers during refueling;

Regulations Applicable to Airports.

- These regulations address handling and storage of fuel and other hazardous materials.

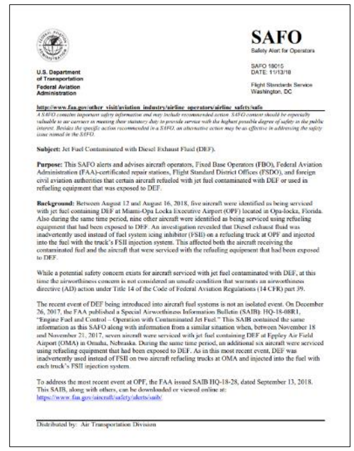
<u>14 CFR Part 139: Certification of airports</u>

§139.321: Handling and storing of hazardous substances and materials.
…
(e) The training required in paragraph (b)(6) of this section shall include at least the following:

(1) At least one supervisor with each fueling agent shall have completed an aviation fuel training course in fire safety that is authorized by the Administrator. Such an individual shall be trained prior to initial performance of duties, or enrolled in an authorized aviation fuel training course that will be completed within 90 days of initiating duties, and receive recurrent instruction at least every 24 consecutive calendar months.
(2) All other employees who fuel aircraft, accept fuel shipments, or otherwise handle fuel shall receive at least initial on-the-job training and recurrent instruction every 24 consecutive calendar months in fire safety from the supervisor trained in accordance with paragraph (e)(1) of this section.

Federal Aviation Administration Bulletins/Alerts

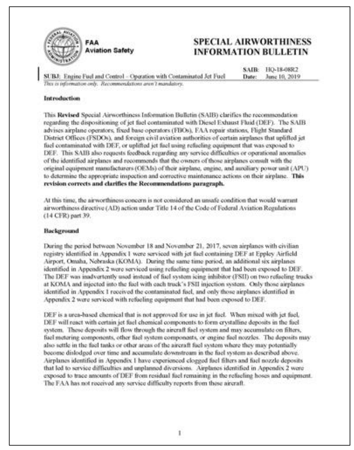
Safety Alert for Operators
Ref. #: 18015
Date: Nov. 13, 2018


SAFO

Summary:

This SAFO alerts and advises aircraft operators, Fixed Base Operators (FBO), Federal Aviation Administration (FAA)-certificated repair stations, Flight Standard District Offices (FSDO), and foreign civil aviation authorities that certain aircraft refueled with jet fuel contaminated with DEF or used in refueling equipment that was exposed to DEF.

Special Airworthiness Information Bulletin
Ref. #: HQ-18-08R2
Date: June 10, 2019

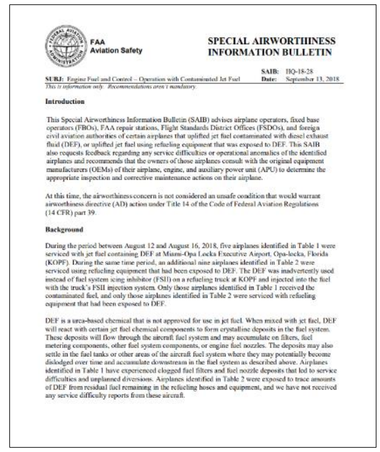

SPECIAL AIRWORTHINESS INFORMATION BULLETIN

Summary:

This Revised Special Airworthiness Information Bulletin (SAIB) clarifies the recommendation regarding the dispositioning of jet fuel contaminated with Diesel Exhaust Fluid (DEF). The SAIB advises airplane operators, fixed base operators (FBOs), FAA repair stations, Flight Standard District Offices (FSDOs), and foreign civil aviation authorities of certain airplanes that uplifted jet fuel contaminated with DEF, or uplifted jet fuel using refueling equipment that was exposed to DEF. This SAIB also requests feedback regarding any service difficulties or operational anomalies of the identified airplanes and recommends that the owners of those airplanes consult with the original equipment manufacturers (OEMs) of their airplane, engine, and auxiliary power unit (APU) to determine the appropriate inspection and corrective maintenance actions on their airplane. This revision corrects and clarifies the Recommendations paragraph.

At this time, the airworthiness concern is not considered an unsafe condition that would warrant airworthiness directive (AD) action under Title 14 of the Code of Federal Aviation Regulations (14 CFR) part 39.

Special Airworthiness Information Bulletin
Ref. #: HQ-18-28
Date: Sep. 13, 2018
Summary:



FAA
Aviation Safety

SPECIAL AIRWORTHINESS INFORMATION BULLETIN

SAIB: HQ-18-28
SUBJ: Engine Fuel and Control – Operation with Contaminated Jet Fuel **Date:** September 13, 2018

This is information only. Recommendations aren't mandatory.

Introduction

This Special Airworthiness Information Bulletin (SAIB) advises airplane operators, fixed base operators (FBOs), FAA repair stations, Flight Standards District Offices (FSDOs), and foreign civil aviation authorities of certain airplanes that uplifted jet fuel contaminated with diesel exhaust fluid (DEF), or uplifted jet fuel using refueling equipment that was exposed to DEF. This SAIB also requests feedback regarding any service difficulties or operational anomalies of the identified airplanes and recommends that the owners of those airplanes consult with the original equipment manufacturers (OEMs) of their airplane, engine, and auxiliary power unit (APU) to determine the appropriate inspection and corrective maintenance actions on their airplane.

At this time, the airworthiness concern is not considered an unsafe condition that would warrant airworthiness directive (AD) action under Title 14 of the Code of Federal Aviation Regulations (14 CFR) part 39.

Background

During the period between August 12 and August 16, 2018, five airplanes identified in Table 1 were serviced with jet fuel containing DEF at Miami-Opa Locka Executive Airport, Opa-locka, Florida (KOPF). During the same time period, an additional nine airplanes identified in Table 2 were serviced using refueling equipment that had been exposed to DEF. The DEF was inadvertently used instead of fuel system icing inhibitor (FSII) on a refueling truck at KOPF and injected into the fuel with the truck's FSII injection system. Only those airplanes identified in Table 1 received the contaminated fuel, and only those airplanes identified in Table 2 were serviced with refueling equipment that had been exposed to DEF.

DEF is a urea-based chemical that is not approved for use in jet fuel. When mixed with jet fuel, DEF will react with certain jet fuel chemical components to form crystalline deposits in the fuel system. These deposits will flow through the aircraft fuel system and may accumulate on filters, fuel metering components, other fuel system components, or engine fuel nozzles. The deposits may also settle in the fuel tanks or other areas of the aircraft fuel system where they may potentially become dislodged over time and accumulate downstream in the fuel system as described above. Airplanes identified in Table 1 have experienced clogged fuel filters and fuel nozzle deposits that led to service difficulties and unplanned diversions. Airplanes identified in Table 2 were exposed to trace amounts of DEF from residual fuel remaining in the refueling hoses and equipment, and we have not received any service difficulty reports from these aircraft.

This Special Airworthiness Information Bulletin (SAIB) advises airplane operators, fixed base operators (FBOs), FAA repair stations, Flight Standards District Offices (FSDOs), and foreign civil aviation authorities of certain airplanes that uplifted jet fuel contaminated with diesel exhaust fluid (DEF), or uplifted jet fuel using refueling equipment that was exposed to DEF. This SAIB also requests feedback regarding any service difficulties or operational anomalies of the identified airplanes and recommends that the owners of those airplanes consult with the original equipment manufacturers (OEMs) of their airplane, engine, and auxiliary power unit (APU) to determine the appropriate inspection and corrective maintenance actions on their airplane.

FAA Letter to airport sponsor – Page 1

U.S. Department of Transportation
Federal Aviation Administration

Office of Airport Safety and Standards

800 Independence Ave., SW.
Washington, DC 20591

OCT 29 2018

Dear Airport Sponsor:

This letter provides awareness of and guidance on handling the inadvertent use of Diesel Exhaust Fluid (DEF) instead of Fuel System Icing Inhibitor (FSII) in aircraft.

Background

In August 2018, the Federal Aviation Administration (FAA) identified five aircraft at an executive airport as being serviced with jet fuel containing DEF. During the same period, the FAA identified nine additional aircraft as being serviced with refueling equipment that had been exposed to DEF. The fueling agent inadvertently used DEF instead of FSII on a refueling truck and injected into the fuel with the truck's FSII injection system.

DEF is a urea-based chemical and is not approved for use in jet fuel. When mixed with jet fuel, DEF will react with certain chemical components in the jet fuel to form crystalline deposits in the fuel system. These deposits will flow through the aircraft fuel system and may accumulate on filters, fuel metering components, other fuel system components, or engine fuel nozzles. The deposits may also settle in the fuel tanks or other areas of the aircraft fuel system where they may dislodge over time and accumulate downstream in the fuel system.

All of the aircraft identified in August did have documented cases of clogged fuel filters and fuel nozzle deposits that led to service difficulties and unplanned diversions.

Recommendations

Bulk fluids are generally stored in hangars or storage areas. Both DEF and FSII are clear and are usually stored in large milky white plastic tanks ranging from 55 gallons to larger cube storage tanks. If stored close to each other, they are very hard to differentiate from each other without very pronounced markings. To prevent confusion, we recommend:

(1) Airport operators and fueling agents do not store DEF and FSII fluids in close proximity to each other;

(2) Airport operators and fueling agents clearly mark bulk storage tanks or barrels with 4-inch or larger stenciled letters visible from all sides. Use "DIESEL DEF" for all DEF fluid and "JET FUEL SYSTEM ICING INHIBITOR" for FSII storage containers; and

FAA Letter to airport sponsor – Page 2

(3) Fueling agents or operators should remove jet fuel suspected of being contaminated with DEF from aircraft and discard it. Do not attempt to repurpose DEF-contaminated fuel to other aircraft or vehicles.

If you have questions, please contact Mr. Dale Williams, Office of Airport Safety and Operations, AAS-300 by email at dale.williams@faa.gov.

Sincerely,

John R. Dermody, P.E.
Director, Airport Safety
and Standards

ASTM Fuel Specifications/Test Methods

- ASTM D910, Standard Specification for Leaded Aviation Gasolines
- ASTM D1298, Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
- ASTM D1655, Standard Specification for Aviation Turbine Fuels
- ASTM D2392, Standard Test Method for Color of Dyed Aviation Gasolines
- ASTM D3227, Standard Test Method for (Thiol Mercaptan) Sulfur in Gasoline, Kerosine, Aviation Turbine, and Distillate Fuels (Potentiometric Method)
- ASTM D4052, Standard Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
- ASTM D4171, Standard Specification for Fuel System Icing Inhibitors
- ASTM D5006, Standard Test Method for Measurement of Fuel System Icing Inhibitors (Ether Type) in Aviation Fuels

Other / Misc. Reference Material

Energy Institute 1538 Handling of Fuel System icing Inhibitor and Aviation Fuel Containing Fuel System Icing Inhibitor at Airports (To be published July 2019, see www.energyinst.org/1538)

- Summary - This publication provides recommended practices for the handling of fuel system icing inhibitor (FSII), also referred to as anti-icing additive, and aviation fuel containing FSII.

A4A bulletin – 2018.4 DEF Contamination of Jet Fuel December 2018

- Summary - The A4A Fuel Technical Committee together with the National Air Transportation Association (NATA) is publishing this bulletin to highlight jet fuel contamination with Diesel Exhaust Fluid (DEF) and to educate the aviation fuel community on the impacts and best practices for using and storing DEF and jet fuel additives.

International Organization for Standardization - ISO 22241- Diesel engines – NOx reduction agent AUS 32 Part 1 Quality Requirements

- Summary - This document specifies the quality characteristics of the NOx reduction agent AUS 32 (aqueous urea solution) which is needed to operate selective catalytic reduction (SCR) converter systems in motor vehicles with diesel engines. SCR converter systems are particularly suitable for selectively reducing the nitrogen oxide (NOx) emissions of diesel engines.

APPENDIX A: ADDITIONAL BACKGROUND ON DIESEL EXHAUST FLUID

What is DEF?

Diesel Exhaust Fluid (DEF) is a nonhazardous, colorless aqueous solution of 32.5% by weight automotive grade Urea dissolved in 67.5% deionized (purified) water. DEF is NOT a fuel additive. It is NOT added to the diesel fuel. DEF is held on a vehicle in a dedicated HDPE plastic or stainless steel tank. The DEF tank is typically 5 – 10 gallons for light-duty vehicles and 10 – 40 gallons for heavy-duty vehicles. Some off road agricultural or construction equipment can have DEF tanks as large as 150 gallons and larger.

The DEF tank fill port generally has a blue colored cap. On trucks, the fill hole is too small to fit a diesel nozzle into, and it is even too small to fit an unleaded gasoline nozzle into. Many diesel vehicles are also fitted with a “mis-fill” prevention magnet that works in conjunction with a DEF “mis-fill” nozzle to allow DEF to only be dispensed into a DEF tank. This can prevent DEF from being pumped into diesel or gasoline tanks.

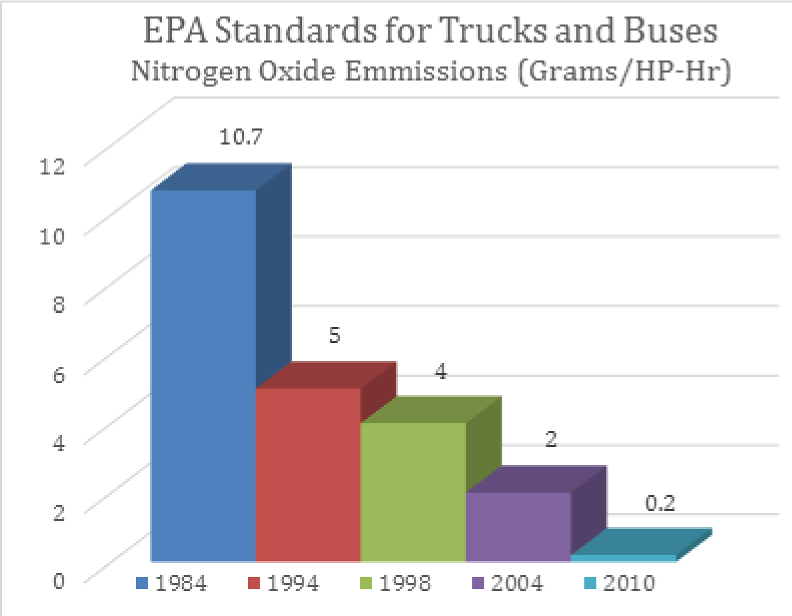
Physical and chemical properties of DEF that are important to know are:

- DEF is heavier than water, having a specific gravity of about 1.09. A gallon of DEF weighs 9.1 lbs, while a gallon of water weighs 8.3 lbs.
- DEF has a slight ammonia smell at room temperature. The ammonia smell becomes stronger and more noticeable with heat.

- DEF has a freezing point of 12°F, so it must be kept in a heated and insulated vessel if stored outdoor in cold climates.
- DEF is not flammable and will not burn under normal conditions.
- DEF is mildly alkaline, with a pH of 9.8-10.0
- DEF is corrosive to active metals such as cast iron, steel, brass, copper, zinc, and aluminum.
- DEF can be irritating to the skin and eyes if it comes in direct contact.
- DEF is slippery to the touch
- When DEF dries, if forms a white residue which can easily be cleaned up with water.

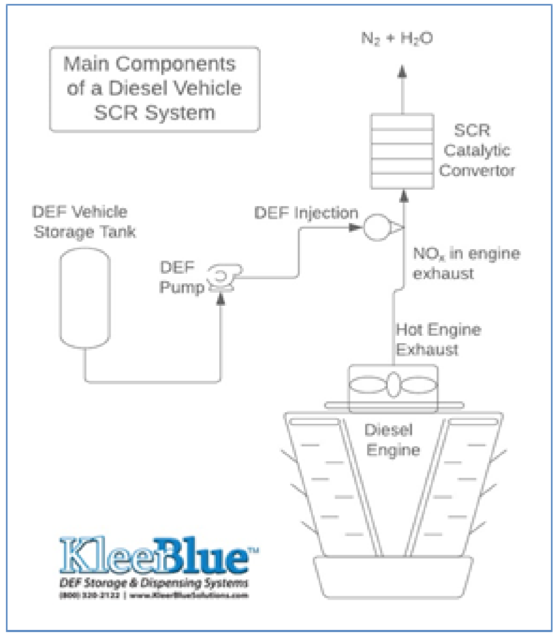
DEF is sold at truck stops, auto part stores, and big box retail stores. It can be purchased in jugs, drums, totes, and at the pump at select truck stops.

Why is DEF Needed?



As part of the new Clean Air Act (CAA) of 1990, the Environmental Protection Agency (EPA) has progressively mandated stronger emission control standards for vehicle engines to curb air pollution. Nitrogen oxides (NOx), Sulfur Dioxide, hydrocarbons, particulate matter and carbon monoxide emissions from vehicles cause health and environmental problems. In diesel engines, NOx emissions can be particularly high, and are a major contributor to smog formation, acid rain, and ground level ozone pollution. NOx has been identified as a major cause of lung damage leading to emphysema and chronic bronchitis. NOx in diesel engine emissions has been targeted for drastic reduction by the EPA. “Clean Diesel” technology has been developed by diesel engine manufacturers in response to EPA regulations.

In 2007, the EPA required that all new on-road heavy duty diesel vehicles manufactured from the year 2010 forward, must meet 0.2 grams of NOx and 0.01 grams of Particulate Matter per brake horsepower-hour. These are drastic reductions, as noted in the graph. To meet these standards, manufacturers have developed aftertreatment technologies such as Diesel Particulate Filters (DPF) and Selective Catalytic Reduction (SCR).



Selective Catalytic Reduction specifically targets the reduction of NOx emissions by injecting Diesel Exhaust Fluid (DEF) directly into a catalytic convertor in the hot exhaust system, downstream of the DPF. The exhaust heat helps to break down DEF into ammonia, which in the presence of the catalyst, reacts with the exhaust NOx to neutralize it into to nitrogen gas and water. Similarly, large scale SCR systems are used at some coal-fired power generation plants to reduce NOx emissions.

How Do We Store and Dispense DEF?

DEF manufacturers and distributors are required to meet strict ISO-22241 standards and be certified by the American Petroleum Institute (API). Purity and correct concentration are critical for the performance of the SCR system and the efficacy of the NOx reduction process. A few parts per million (ppm) contamination of minerals like sodium, potassium, and other active metals in DEF can cause the catalytic convertor to lose its effectiveness, to the point that it will no longer remove NOx from the exhaust. Sensors on the vehicle exhaust system will shut down the engine, or severely restrict its performance, if NOx is detected in the engine emissions. If this happens, it can be quite costly to repair or replace the damaged SCR equipment.

Particulate contamination of DEF (dirt, dust, organic matter, plastic or metal shavings) can also damage a vehicle SCR system. The vehicle DEF pump, and the atomizing nozzle that sprays DEF into the catalytic convertor, can both be damaged by particles in the DEF. It is recommended that a 1-micron filter be utilized in the DEF dispensing equipment to prevent particles from entering the vehicle DEF storage tank.

It is important to know the materials that are recommended to be used with DEF, and those that must be avoided. **<u>Recommended</u>** materials include:

- 300 series Stainless Steel
- Polypropylene and Polyethylene plastic
- EPDM and Viton gaskets and seals
- Special, approved hose, labeled for use with DEF

Materials to **avoid** include:

- Cast Iron, black iron, carbon steel, plated steel, or galvanized steel.
- Aluminum, plated aluminum, or anodized aluminum
- Brass, bronze, copper, zinc, lead, magnesium, and silver
- PVC and CPVC plastic.

All equipment used to store and dispense DEF must be new (not used to store or dispenser another product) and should be rinsed with deionized (DI) water or DEF before use. City tap water or well water will leave a contaminates and should not be used to rinse a DEF tank or equipment. When first using a DEF dispenser, the first few gallons of DEF dispensed should not be put into a vehicle DEF storage tank, but rather disposed of.

DEF will freeze at 12°F but freezing itself does not permanently harm the DEF solution. Once it melts and becomes liquid again, the DEF will still work to remove NOx from diesel exhaust in an SCR system. However, freezing could damage the DEF storage and dispensing equipment, and should be avoided at all costs.

Storage life of DEF is temperature dependent. Ideal storage temperatures are 40°-75°F. DEF can remain fully viable for up to 2 years at this storage temperature. It is generally agreed that higher storage temperatures can reduce the storage life of DEF as follows:

- 75°F or lower = 2 years
- 86°F or lower = 1 year
- 95°F or lower = 6 months

Diesel vehicles equipped with SCR will heat the vehicle DEF storage tank with a warm antifreeze heat exchanger when it is cold outside. When the engine if off, the DEF is allowed to freeze in the tank. Once started, the vehicle computer does not check for NOx in the exhaust immediately, but rather has a grace period of about 45 minutes until the DEF thaws in the tank and lines and can start being added to the catalytic convertor.

Dosage rates depend on the vehicle and engine manufacturers, but generally are 2 - 6% of the rate of diesel consumption.

The EPA has adopted multiple tiers of emission standards.

- 2010 On-Road Diesel
- 2014 Off-Road Diesel
- 2014 Largest C2 Marine
- 2015 Locomotives

- 2016 C3 Ocean Vessels
- 2017 C1 Marine

APPENDIX B: EXAMPLE FUEL SYSTEM ICING INHIBITOR RESERVOIR LABEL

APPENDIX C: AOPA AIR SAFETY INSTITUTE SAFETY NOTICE

ASI SAFETY NOTICE

AOPA AIR SAFETY INSTITUTE™

The Issue:

Diesel Exhaust Fluid (DEF) is a colorless additive used with diesel engines to reduce emissions. It has mistakenly been added to jet fuel on three occasions over the past 18 months. Presumably, operators have mistaken DEF for fuel system icing inhibitors (FSII), which are also colorless. The latest DEF contamination incident caused engine flameouts at altitude in two Cessna 550 jets, one of which experienced dual-engine flameout resulting in a total engine failure landing at a Savannah, GA airport.

What You Should Do:

Talk with your fuel providers and ask if they use DEF in ground equipment. If so, inquire about procedures to confirm correct additives are used for jet fuel. This should include separate storage, clear labeling, confirmation of correct additives at the time of insertion, and training for personnel.

DEF crystalizes in jet fuel and clogs fuel filters, which can result in fuel starvation. If engine failure occurs due to turbine flameout, be cognizant of the potential for DEF contamination. Follow emergency checklist procedures for engine failure and realize if DEF contamination is the cause, successful restart is unlikely. If a turbine engine flameout occurs in a multi engine aircraft, follow emergency checklist procedures and expect loss of the remaining engine(s). Consider preserving altitude for as long as possible to maximize potential of a safe glide to a suitable runway.

If you encounter or suspect any DEF contamination, notify the Fixed Base Operator where fuel was obtained as soon as possible. Document the incident and report it to the local FAA FSDO office immediately.

What You Should Know:

There are no known pre-flight procedures pilots can use to identify the presence of DEF in jet fuel.

An industry working group, which includes AOPA is working to understand causes of contamination and provide recommendations for prevention.

Read AOPA's article https://www.aopa.org/news-and-media/all-news/2019/may/22/new-def-fuel-contamination-incidents-reported

To increase safety awareness and help reduce accidents, the AOPA Air Safety Institute periodically issues Safety Notices to remind pilots of significant safety topics.

APPENDIX D: NATA SAFETY 1ST ALERT – DEF CONTAMINATION

National Air Transportation Association
The Voice of Aviation Business

818 Connecticut Avenue, NW, 900 Washington, DC 20006
P (202) 774-1535 (800) 808-6282
www.nata.aero

Date: June 4th, 2019
Document: SFA_2019_001

Safety 1st Alert – Critical Issue – DEF Contamination

Last month, another jet fuel contamination event occurred at an FBO in Southwest Florida. This latest incident marks the third time in 18 months that Diesel Exhaust Fluid, or DEF has contaminated the fuel supply of a jet fuel truck. In all three cases, multiple in-flight engine failures occurred, with the possibility of significant damage to aircraft fuel systems and engines. Fortunately, none of these cases resulted in an aircraft crash.

Following the first contamination incident in late 2017, NATA, through its Safety Committee, reviewed the risk of jet fuel contamination with DEF and created a free DEF Contamination Prevention training course. This most recent incident, however, highlights yet again, just how serious the DEF contamination risk is, and how it is still a very real threat. FBOs and aircraft operators must be diligent in ensuring that staff are not only properly trained, but that company policies and procedures used to prevent DEF contamination are being followed.

The following Q & A highlights key information all FBOs and fuel providers should be aware of.

- **What is Diesel Exhaust Fluid (DEF) and what is it used for?**
  DEF is a urea and water-based fluid that is required by federal regulations to be used in the emission reduction systems of modern diesel engine vehicles. DEF is NOT a fuel additive, aviation or otherwise. It is a clear liquid, stored in a specialized tank on the chassis of diesel engine vehicles, that is then injected into the engine exhaust to promote reduction of noxious emissions.

- **How does DEF get into jet fuel?**
  Details of the latest incident are still pending, but in previous incidents, the identified risk involves line service personnel mistaking DEF for Fuel System Icing Inhibitor (FSII, Prist®, Dice® DiEGME) and adding DEF to the FSII storage tanks on mobile refuelers. DEF and FSII are both clear, colorless liquids and if

DEF is mistakenly added to a FSII storage tank, contamination can be very difficult, if not impossible to detect.

- **What happens when DEF contaminated jet fuel is delivered to aircraft?** Although the exact mechanism is unclear, the urea in DEF reacts with certain jet fuel chemical components to form crystalline deposits in the fuel system. These deposits then flow through the aircraft fuel system and accumulate on fuel filters and other fuel system components which can and has led to inflight engine shutdowns (see figures 1, 2 and 3).

Figure 1: DEF crystallization on aircraft fuel screen.

Figure 2: DEF crystallization on aircraft fuel filter.

Figure 3: DEF crystallization in aircraft fuel tank.

- **Has there been any guidance from the FAA on the issue of DEF contamination?**
  Yes. Click the links below for more information:
  SAIB HQ-18-28
  SAFO 18015

- **What can FBOs and other fuel providers do to reduce the risk of DEF contamination?**
  In addition to the above guidance offered by the FAA, NATA recommends FBOs and other fuel providers reference the Safety 1st Operational Best Practice *OBP-36 DEF Handling and Contamination Prevention.*

- **What should I do if I believe that jet fuel has been contaminated with DEF?**
  Discard any jet fuel that has been removed from an affected aircraft because it is suspected of being contaminated with DEF. The contaminated fuel should not be used on aircraft or other vehicles. NATA recommends that all FBOs and other aviation fuel providers work with their fuel distributer to develop a response protocol to aviation fuel contamination incidents. Such a protocol should include the training needs for FBO staff.

- **How can my team access the free NATA Safety 1st DEF Contamination Prevention training?**
  1. Companies that currently use the NATA Safety 1st program can simply assign DEF Contamination Prevention training as they would any other Safety 1st course.

  2. Companies that do not currently use the NATA Safety 1st program can contact us at safety1st@nata.aero for complementary access to the DEF Contamination Prevention training.

  3. We are working on bringing DEF Contamination Prevention training to www.preventmisfueling.com, where NATA currently offers a free Misfueling Prevention training program. A press release will be issued once available.

For more information or for additional questions please contact NATA at safety1st@nata.aero

ACKNOWLEDGEMENTS

AOPA, GAMA, NATA, and NBAA wish to thank the members of the Aircraft Diesel Exhaust Fluid Contamination Working Group for their engagement to generate this resource to mitigate the hazard of aircraft diesel exhaust fluid contamination of aviation fuel.

Ryan Alfonso
FAA

Alex Beringer
Fairwinds Air Charter

Ron Bojanski
Midwest Aviation

Hardy Bullock
Truckee-Tahoe Airport

Robb Burbach
Union Pacific Railroad

Keith Clark
Phillips 66

Brian Coyle
Signature Flight Support

Megan Eisenstein
NATA

John Endicott
FAA

Michael France
NATA

Reed Fuller
World Fuel Services

Jim Gammon
Gammon Technical Products

Ross Gregson
Phillips 66

Giovanni Hanna
Dassault Falcon Jet

Randy Harrison
AvFuel

John Hathaway
Murray Equipment, Inc.

Tom Huff
Gulfstream Aerospace

Mark Larsen
NBAA

John Lindner
Epic Fuels

Monica Merritt
FAA

Dan Murray
Total Control Systems

Stuart Ochs
Sheltair

David Oord
AOPA

Mark Rumizen
FAA

Joe Sambiase
GAMA

Bob Schick
TAC Air

Eduard Stalzer
FAA

Brad Van Camp
AvFuel

Peter White
FAA

Cody Waterman
TAC Air

Dale Williams
FAA

Jamie Wilson
FBO Partners

Jeff Wofford
CommScope