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INTERIM BASE-LEVEL GUIDE FOR EXPOSURE TO JET FUEL AND ADDITIVES

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This report provides interim guidance on evaluating exposures to the most common jet fuel and additives used in the U.S. Air Force, Jet Propulsion Fuel-8 (JP-8). The report is "interim" because there are a number of emerging fuels such as synthetic paraffinic kerosene and biofuels that are already approved for use on Air Force weapon systems but whose occupational and environmental exposure limits (OEELs) are not well-defined. OEELs recommended in this report for JP-8 should be sufficiently conservative to be applied to emerging fuels and their blends with JP-8. Contract efforts are currently underway to evaluate the toxicity of emerging fuels, and the U.S. School of Aerospace Medicine/Occupational & Environmental Health Department anticipates further exposure guidance will be issued from those efforts.

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1.0 SUMMARY

This report provides interim guidance on evaluating exposures to the most common jet fuel and additives used in the U.S. Air Force, Jet Propulsion Fuel-8 (JP-8). The report is "interim" because there are a number of emerging fuels such as synthetic paraffinic kerosene and biofuels that are already approved for use on Air Force weapon systems, but whose occupational and environmental exposure limits (OEELs) are not well-defined. OEELs recommended in this report for JP-8 should be sufficiently conservative to be applied to emerging fuels and their blends with JP-8. Contract efforts are currently underway to evaluate the toxicity of emerging fuels, and the U.S. Air Force School of Aerospace Medicine/Occupational & Environmental Health Department anticipates further exposure guidance will be issued from those efforts.

2.0 INTRODUCTION

Jet Propulsion Fuel-8 (JP-8) is used in U.S. Air Force aircraft and support equipment. It is nearly identical to commercial aviation fuel (Jet-A), with the exception of additives used to enhance performance (Table 1). For additional information on JP-8, refer to military specification MIL-DTL-83133E (Ref 1).

Table 1. Common JP-8 Additives

Additive	Usual Chemical Identity	Special Notes
Fuel-system icing inhibitor	diethylene glycol monomethyl ether RTECS #KL6125000 0.10%-0.15% v/v in fuel	Reproductive toxicant concentration in water found in tank bottoms may be as high as 30%-50% v/v
Static dissipater	Stadis 450 mostly toluene, various trade-secret polymeric compounds	Reproductive toxicant
Metal deactivator	N,N'-disalycylidene-1,2-propanediamine (5.7 mg/L) RTECS #GP3130000	
Antioxidant	17-24 mg/L, of any number of six common alkyl phenolic compounds	

3.0 HAZARD EVALUATION

3.1 Process Assessments

Assessments should be conducted in accordance with Air Force Instruction 48-145, *Occupational and Environmental Health Program* (Ref 2). Processes that involve potential exposure to JP-8 should be documented in the Defense Occupational and Environmental Health Readiness System.

The most common route of exposure to jet fuel is by skin contact. Identify any processes where workers may have the opportunity to come into contact with liquid fuel, either in aircraft or ground-based equipment, tanks, pipes, storage bowsers, and so forth. Because JP-8 has a relatively low volatility, focus on processes that could leak or drip JP-8 onto permeable clothing like ABUs and stay in close contact with the skin throughout the work day or be carried home to family members.

Certain processes, such as pulling foam from an aircraft fuel tank, present a high potential for skin exposure. Workers should immediately wash off any jet fuel from the skin with soap and water. Any clothing that becomes saturated with fuel should be changed. Failure to immediately wash off the fuel may result in skin irritation.

Because of strict controls normally in place for permit-required entry into confined spaces [Air Force Occupational Safety and Health (AFOSH) Standard 91-25 (Ref 3)], airborne exposures for entry into fuel tanks are usually well controlled. Engine start operations under low ambient temperature conditions can produce large amounts of uncombusted and aerosolized fuel. Pay close attention not only to ground crew who may work around cold-start areas but also to potential downwind populations. Clouds or mists coming from turbine exhaust in cold settings may not be steam—the cloud could actually be aerosolized fuel.

Special consideration should be given to areas where water collects and settles to the bottom of fuel tanks. Water in fuel tanks presents several potential hazards. The first is that deicing compounds in JP-8 are designed to preferentially partition into the water phase and lower its freezing point. This means that concentrations of deicer in water found at the bottoms of fuel tanks could be as high as 30%-50% on a volume basis. This would present primarily a skin contact hazard to personnel involved in fuel drainage or sumping operations or at oil-water separators.

The presence of water anywhere in fuel systems also creates an environment ripe for microbial growth. Because the microbes that grow in fuel tank bottoms may include potential human pathogens (Ref 4), the health hazards of colonized fuel would be similar to those for workers who are exposed to wastewater or sewage. Workers who have potential contact with colonized fuel samples or tank sediments should be identified to the Occupational and Environmental Health Working Group (OEHWG) so that their immune status and potential for exposure to reproductive toxicants found in JP-8 can be determined.

Microbial growth in fuel sumps can be identified visually by the presence of a slimy biofilm that floats at the fuel-water interface or by fuel that is not clear and bright or that has a sour odor. Operational concerns can arise from the ability of biofilms to foul and plug fuel lines, leading to engine starvation. Colonized fuel can also "infect" previously uncontaminated fuel through the use of common bowsers or storage tanks. Bioenvironmental engineering expertise in drinking water and wastewater management can help the logistics community to identify areas for potential cross-contamination of fuel. Diagnostics tests (such as quantitative real-time polymerase chain reaction) for detecting microbial growth in fuel are currently under development by the Air Force Research Laboratory (AFRL/RZPF). The potential health hazards of microbial growth in fuels is a complex and emerging issue. If you have questions about microbial growth in fuels, please contact the U.S. Air Force School of Aerospace Medicine (USAFSAM) Environmental, Safety, and Occupational Health (ESOH) Service Center (DSN 798-3764, 1-888-232-ESOH (3764), or esoh.service.center@wpafb.af.mil).

3.2 Exposure Monitoring

Airborne exposures to JP-8 vary widely over time and activity and are also influenced by climate and different refinery blends. A broad survey of Air Force personnel has characterized tasks with the highest potential for airborne exposures (Ref 5). The highest exposures occur inside poorly ventilated hangars and involve tasks related to fuel tank-entry, tank-entry attendant/runner/fireguard, and leak detection. Cold engine startups in any area can produce significant aerosol exposures to uncombusted fuel. Vapor sampling for JP-8 on the flight line is generally not warranted.

To sample for JP-8 vapor exposure, use the National Institute for Occupational Safety and Health (NIOSH) Method 1550, "Naphthas." Submit a bulk sample (5 mL) along with the air sample for best results. For screening samples, direct-reading instruments can be used. PERMEA-TEC™ pads (SKC, Eighty Four, PA) may be used to help monitor for and protect against skin contact from personal protective equipment (PPE) failure or breakthrough. The benzene concentration in JP-8 is typically very low (less than 0.05%) and is at least 10 times less than the benzene concentration in JP-4. However, the benzene content of JP-8 can vary widely depending on the supplier and aging conditions of the fuel. Operations to remove fire-suppressant foam have historically resulted in the highest airborne benzene exposures from JP-8. Career fields with the potential for exposure to benzene include those involved in fuel handling and distribution along with those involved with fuel and aircraft systems maintenance, especially Air Force Specialty Codes 2A64x4, 2A6x1, 2A3x3, 2A5x1, 3E4xC1, and 2F0X2.

To sample for airborne benzene, NIOSH Method 1501 for aromatic hydrocarbons should be used. If airborne exposure levels to benzene exceed 1 ppm [8-h time-weighted average (TWA)], the Occupational Safety and Health Administration (OSHA) benzene standard, Code of Federal Regulations (CFR) Title 29, Part 1910.1028, has specific requirements for establishing regulated areas and periodic workplace sampling protocols (see Appendix) (Ref 6). OSHA's *Sampling and Analytical Methods: Benzene* provides additional guidance (Ref 7).

3.3 Occupational and Environmental Exposure Limits (OEELs)

Since Air Force Manual 48-155 superseded AFOSH Standard 48-8, a legal or peer-reviewed occupational and environmental exposure limit (OEEL) for jet fuel has not been available. Based on a National Research Council (NRC) study contracted by the Air Force, USAFSAM currently suggests using 200 mg/m^3 (8-h TWA) for JP-8 vapor and 5 mg/m^3 (8-h TWA) for aerosol as interim OEELs (Ref 8). Augmenting the NRC's study, additional in-depth and up-to-date toxicity, mode of action, health, and exposure guidance on JP-5 and 8 can also be found in the National Advisory Committee on Acute Exposure Guideline Levels document, "Jet Propellant Fuels 5 and 8 Acute Exposure Guideline Levels" (see Ref 9).

Routine sampling to characterize airborne exposure to JP-8 should normally focus on vapor-phase. The main area where aerosol sampling may be warranted would be in cold engine start operations, where as much as 30%-40% of fuel leaving the engine is uncombusted. For most operations, vapor sampling should be sufficiently conservative. However, if you identify a need to perform aerosol sampling for JP-8, please contact the USAFSAM-ESOH Service Center.

Additionally, because of the adoption of new synthetic versions of JP-8, such as synthetic paraffinic kerosene (SPK), these new blends have no OEEL yet established. USAFSAM suggests using this interim guidance until the data gaps outlined in section 5.0 of this report have been addressed. The best current data suggest existing JP-8 OEELs are more conservative than those that might be derived from initial studies of JP-8/SPK blend toxicity studies.

As previously noted, the benzene content of JP-8 is typically low – median values for military fuel maintenance workers are 78 ppb and median values for military fuel handling/distribution/recovery/testing workers are 2 ppb (Ref 10). Nevertheless, for purposes of safety and compliance with current OSHA guidance wherever monitoring for benzene is warranted, the most current OSHA standards apply.

3.4 Respiratory Protection

Respirators shall be worn, as directed by the base Bioenvironmental Engineering office, in accordance with AFOSH Standard 48-137, *Respiratory Protection Program* (Ref 11).

3.5 Protective Clothing and Equipment

Personnel who may come into contact with JP-8 should wear appropriate PPE (e.g., butyl and nitrile rubber gloves, neoprene rubber headwear/footwear, coveralls). Personnel who have prolonged, direct contact with JP-8 (e.g., fuel cell workers) must wear a tri-layer coverall, including bootie [see Technical Order 1-1-3 (Ref 12)]. This coverall is a tri-layer, anti-static laminate consisting of a nylon filament face, a Teflon®/Gore-Tex® membrane, and nylon knit with anti-static filaments incorporated into the fabric structure. To protect against leaks, joints between the tri-layer coverall and boots and gloves should be secured with elastic bands, tape, or other means. For details on permit-required confined space entry procedures and PPE, see AFOSH Standard 91-25 (Ref 3).

4.0 MEDICAL SURVEILLANCE

These recommendations apply to any worker who is exposed above the action level of JP-8 (100 mg/m^3) or who has a significant dermal exposure to jet fuel. Significant exposures include those tasks in which a worker comes into prolonged contact with jet fuel on a routine basis (e.g., fuel cell worker). The initial and annual medical surveillance should include a health history and physical exam. The health history should focus on pulmonary, dermal, neurologic, renal, and hepatic systems. The physical exam should focus on the skin. Special note should be made of potential for contact with water and sediments found in the bottom of fuel tanks, as outlined in section 3.1. Additional medical surveillance activities may be approved by the base OEHWG based on unique mission requirements or exposures.

5.0 AREAS UNDER FURTHER STUDY

USAFSAM has developed problem statements for JP-8 health risk assessment that are currently under study. These include:

- Microbial growth in fuels
- Further toxicological characterization of SPK-blended fuel vapors and aerosols
- Methods of exposure assessments to aerosolized JP-8
- Lack of OEELs for SPK or other JP-8 variants
- Absence of Air Force-specified methods for measuring atmospheric exposure concentration of JP-8/SPK blends

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APPENDIX

OSHA Benzene Standard

Benzene 29 CFR §1910.1028

Scope: Applies to all occupational exposures to benzene except:

1. Storage, transportation, distribution, dispensing, sale, or use of gasoline, motor fuels, or other fuels containing benzene subsequent to its final discharge from bulk wholesale storage facilities. *Exception: The requirements do apply where gasoline or motor fuels are dispensed for more than 4 hours per day in an indoor location.*
2. Loading and unloading operations at bulk wholesale storage facilities that use vapor control systems for all loading and unloading operations.
3. Storage, transportation, distribution, or sale of benzene or liquid mixtures containing more than 0.1% benzene in intact containers or in transportation pipelines sealed so they contain benzene vapors or liquids.
   Exception to both 2 and 3: Hazard communication requirements in §1910.1200 and emergency requirements in §1910.1028 (g) and (i)(4) do apply to both of these types of operations.
4. Containers and pipelines carrying mixtures with less than 0.1% benzene.
5. Work where the only exposure to benzene is from liquid mixtures containing 0.1% or less of benzene by volume.

Initial Determination

Breathing zone air samples (taken after 12/10/1986) representing the 8-hour TWA and the15-minute exposures of employee(s) in each work area, each job classification, and each work shift (unless it can be documented that one shift will consistently have the highest exposure; then only one shift must be sampled).

Note: Objective data may be used only to determine where short-term exposure limit monitoring is needed.

Notification of employees [§1910.1028(e)(7)] within 15 "working days" after receipt of results.
Records of exposure measurements complying with §1910.1028(k)(1) must be maintained for at least 30 years.

Any exposure level	Level > AL (0.5 ppm)[a]	Level > PEL-TWA (1 ppm)[a]	Level > STEL (5 ppm)[a]
▼	▼	▼	▼
Monitoring for the STEL must be "repeated as necessary to evaluate ... short-term exposures" - Monitoring must be initiated if changes might result in exposure > TWA or > STEL, or if there is reason to suspect exposure may be > TWA or > STEL	Periodic monitoring at least every 12 months Notification of Employees [§1910.1028(d)(7)] within 15 "working days" of results - Monitoring may cease for employees represented by the monitoring if results are < (AL (see requirements under "Any exposure level")	Periodic monitoring at least every 6 months Notification of Employees [§1910.1028(d)(7)] within 15 "working days" of results - Monitoring may cease for employees represented by the monitoring if results are < AL (see requirements under "Any exposure level")	No periodic monitoring specified; however, monitoring for the STEL must be "repeated as necessary to evaluate ... short-term exposures"
Protective clothing and equipment must be worn where needed to prevent eye contact and/or skin exposure to liquid		Methods of compliance: If feasible, engineering or work practice controls must reduce levels < TWA/STEL. Where documented exposures occur < 30 days/year, engineering or work practice controls must reduce TWA < 10 ppm, where feasible. A written compliance program must be developed for implementing these controls. Regulated areas must limit access to authorized protected employees, with signs complying with §1910.1028(j)(1). Respirators must be used when exposures exceed the TWA and/or the STEL and for emergencies. A respirator program must comply with §1910.134(b) – (d), [*except (d)(1)(iii), (d)(3)(iii)(B)(1)& (2)*] and (f) – (m). Respirator selection must meet the minimum requirements in Table 1 of 29 CFR §1910.1028(g).	

Emergency urine test must be given within 72 hours to employee(s) exposed to benzene in an emergency	Medical exams must be available for employees exposed > AL for 30 days/year or more	Medical examinations must be available for employees exposed > TWA and/or STEL for 10 days/year or more - Medical exams in §1910.134 for the use of respirators apply to any number of days per year
Initial training is required where benzene is present	Initial and annual training required where exposures > AL	
Training must cover §1910.1200(h)(1) and (2); §1910.1028 requirements; Appendices A, B, C; and medical exams		
Records of medical surveillance must include a "physician's written opinion" and other data to comply with §1910.1028(k)(2)		

[a]**OSHA benzene exposure limits:**

ppm	Standard	Comment
0.5	action level (AL)	
1	permissible exposure limit (PEL) (8-h TWA)	
5	short-term exposure limit (STEL) (15 min)	
10	PEL (8-h TWA)	applies to functional areas exempt from benzene standard per CFR 1910.1028 (see 29 CFR 1910.1000, Table Z-2)
25	ceiling	applies to functional areas exempt from benzene standard per CFR 1910.1028 (see 29 CFR 1910.1000, Table Z-2)
50	10-min peak	applies to functional areas exempt from benzene standard per CFR 1910.1028 (see 29 CFR 1910.1000, Table Z-2)

LIST OF ABBREVIATIONS AND ACRONYMS

AFOSH	Air Force Occupational Safety and Health
AL	action level
CFR	Code of Federal Regulations
ESOH	Environmental, Safety, and Occupational Health
JP	jet propulsion
NIOSH	National Institute for Occupational Safety and Health
NRC	National Research Council
OEEL	occupational and environmental exposure limit
OEHWG	Occupational and Environmental Health Working Group
OSHA	Occupational Safety and Health Administration
PEL	permissible exposure limit
PPE	personal protective equipment
SPK	synthetic paraffinic kerosene
STEL	short-term exposure limit
TWA	time-weighted average
USAFSAM	United States Air Force School of Aerospace Medicine