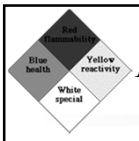
Occupational Toxicology (the Flightline)

Dr. John Campbell, MFS
Aviation Medicine

November 2, 2011



Hazards on the Flightline

- As an aeromedical physician you have a responsibility to:
  - The Mission
  - Your Commander
  - Your patient
  - Your patient's family
- Hazardous exposures are all around the flightline

Be Aware & Be Informed!

Flightline Occupational Medicine

(Uniqueness of our practice when compared to Primary Care)

Primary Care	**Occupational Medicine**
• Patient focused	• Mission focused
• Patient-based health care	• Population-based health care
• Little regulations (unless HMO)	• Highly regulatory environment
• Patient disposition	• Patient disposition
✈ "Is the patient feeling better"	✈ "Is the patient able to function and contribute to the mission"
• Little if any team approach	• Medical team approach
	✈ Commanding Officer, Industrial Hygienist, Safety Officer

Flightline Occupational Medicine

(Uniqueness of our practice - Primary Prevention)
"Prevent the disease or injury from occurring"

- Prevention of hazard creation
  - ✈ Substitution of hazardous materials, change the number (or aerodynamics) of helicopter rotor blades to reduce vibration
- Modify the relevant qualities of the hazard
- Reduce the amount of generated hazards
  - ✈ Change the work method to minimize the toxin output
  - ✈ Modernized jet engines to reduce fumes/excessive noise
- Prevent the release of the hazards that already exits
  - ✈ Ventilation hoods, closed circuit refueling systems
- Make the worker resistant to damage from the hazard
  - ✈ training, immunizations, physical fitness

Flightline Occupational Medicine

(Uniqueness of our practice - Secondary Prevention)
"Reversal of a injurious process"

- Modify the rate of hazard release from its source
  - ✈ Stroking seats in a helicopter, Crushable ear cups
- Separate in time/space, the hazard from the worker
  - ✈ Limit the exposure time of noises greater than 85dB
  - ✈ Ionizing Radiation Health program
  - ✈ Radiation zones for Microwave radar dishes
- Separate the hazard from the worker by a material barrier
  - ✈ Sound enclosures for high dB generating machines, lead walls/aprons of x-ray technicians, laser goggles

Flightline Occupational Medicine

(Uniqueness of our practice - Tertiary Prevention)
"Enable reintegration of a worker after an illness or injury"

- Begin to counter the damage already done by the hazard
  - ✈ Provide additional hearing protection for personnel with STS
  - ✈ Enforce annual noise surveillance
  - ✈ CFR always on the flight line
- Stabilize, repair and rehabilitate the object of the damage
  - ✈ Splints/braces after an injury

Flightline Occupational Medicine

Regulations

- Occupational medicine is a highly regulatory specialty
- Flightline related federal health regulations
  - ✈ American Disability Act (ADA)
  - ✈ Occupational Safety Health Act (OSHA)
  - ✈ National Institute for Occupational Safety & Health - NIOSH (advisory in nature)
  - ✈ Federal Aviation Administration (FAA)
- Military service regulations
  - ✈ Aeromedical Standards, AR's, DA-PAM's, DOD Pubs

History

- More than 1 million personnel work in the aerospace field
  - ✈ Pilots, mechanics, ground crew, and aircrew
  - ✈ Each of these occupations are exposed to unique toxic risks.
- - 654,088 pilots in the US (commercial/recreational)
- - 571,358 Non-pilot aviation crew
  - ✈ aircraft mechanics
  - ✈ parachute riggers
  - ✈ flight engineers and navigators

The First Aviation Toxicological Hazards

- First fuels used a Castor oil mix for lubrication
- Front positioned engine caused a continual mist of castor oil to be spayed across the pilot's face
- Aviators wore long scarves to wipe mist from their goggles and cover their mouth & nose
- What did the ingested/inhaled castor oil do to the aviator?

Definitions

Aerosol

Liquid droplets or solid particles dispersed in air. (0.01-100 µm)

Dust

Solid particles generated by handling, crushing, grinding, rapid impact or detonation of organic or inorganic material. Settle under force of gravity.

Fume

Airborne particulate formed by condensation of a solid particle from a gas. (< 1µm)

Definitions II

Smoke

Air suspension or aerosol of particles originating from combustion or sublimation. Generally contains droplets and dry particles.

Vapor

Gaseous form of a substance that is normally a liquid or a solid at room temperature.

Exposure Limits

TLV's

Threshold Limit Values

MEL's

Maximum Exposure Limits

MAC's

Maximum Acceptable Concentrations

PEL's

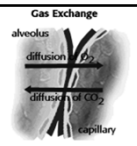
Permissible Exposure Limits

NOEL

No observable effect Level

TLV's

- Three types:
  - TWA (time weighted average)
  - STEL (short term exposure limits)
  - TLV-C ceiling
- Also Publish
  - Biological Exposure Indices
  - Skin notation



Toxin Routes into the Body

Toxin Inhalation

- The most important method
- The normal alveolar surface area ranges between 50 to 100 square meters (m^2)
  - 70 m^2 approximates the surface area of a tennis court.
- When inhaled, most toxins absorb directly into blood stream.

Cutaneous Absorption

- Prolong contact with most Petroleum, oils, lubricants (POLs) may allow for dermal absorption.
- Physical handling of a toxic product is not the only method of absorption
  - Fuel contaminated clothing

POLs = Petro/Oils/Lubricants

Toxin Ingestion

- Intentional
  - Suicide attempts are an unfortunate reality of our failure to pick up the signs and symptoms of problems within our patient population
- Unintentional
  - Eating, drinking or smoking during aircraft preflight checks ?
  - Flying with fuel contaminated flight gloves ?
  - Crews drinking/eating foodstuffs in flight with gloves on ?

Toxic Fumes

Categorization: Mech of Action

- Simple asphyxiants
  - CO^2, Halon, Methane
- Chemical asphyxiants
  - CO, HC, HS
- Upper respiratory tract irritants
  - Higher Water solubility
    - Isocyanates, Sulfur dioxides
- Lower respiratory tract irritants
  - Lower Water solubility
    - Nitrogen Oxides

Categorization: Worksite Exposure

- Flight line exposures
  - POLs*, products of combustion
- Maintenance/Service exposures
  - POL's*, Solvents, dust, radiation
- Emergency response exposures
  - POL's*, dust/composite fibers, Biohazards

POLs = Petro/Oils/Lubricants

Aviation Fuels

Most engine fuels are a combination of multiple petroleum products

Army jet engines use JP-8 (NATO F_{34})

- NATO fuel since 1972
- Important fractions include:
  - Mixture of 100s of discrete chemicals
  - Alkanes C_8 –C_{15} (81%)
  - Aromatics (19%)
    - Benzene, tolulene, naphthalene, xylene
- Flash Point - 100 F°

Navy jet engines use JP-5 (NATO F_{44})

- Mixture of C_4-C_{14} Hydrocarbons
- Important fractions include:
  - Benzene 0.5%, Tolulene 1.33%, Ethyl-benzene 0.37%, Xylene mix of 2.32%
- Flash Point - 140 F°
- Old - jet engine use JP-4

Aviation Fuels

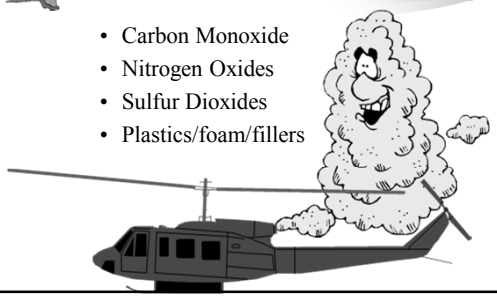
(Symptoms of Acute Exposure)

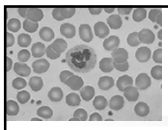
- Neurological symptoms
  - Light-headedness, confusion, fatigue, coma, slurred speech, respiratory failure, impaired psychomotor
- Cardiac and Respiratory symptoms
  - Irregular heart beats, coughing, choking, wheezing
- Gastrointestinal symptoms
  - Nausea, vomiting, easily absorbed through mouth
- Skin symptoms
  - Chemical burns, irritation due to the drying effect

Products of Combustion

(Thermal Decomposition)

- Carbon Monoxide
- Nitrogen Oxides
- Sulfur Dioxides
- Plastics/foam/fillers



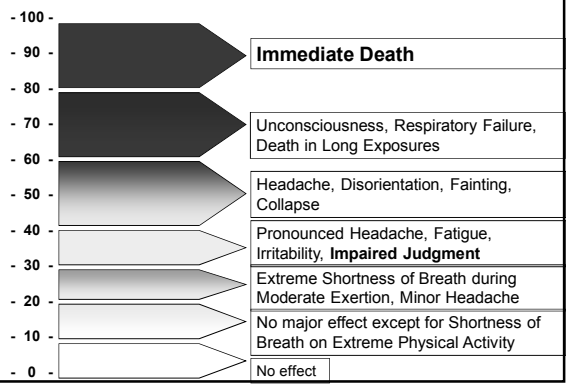


Carbon Monoxide

- Most common cause of fatal poisonings in USA
- A chemical asphyxiant from incomplete combustion
- CO is a colorless, odorless gas
  - ✈ Binds to hemoglobin 256x greater affinity than oxygen
  - ✈ Intracellular poison, inhibiting Cytochrome P-450
- Engine exhaust gases
  - ✈ Reciprocating - 8.5% CO at takeoff, 3.0% CO at cruise
  - ✈ Turbine -CO exhaust from warm engine - Minimal
- Crash Sequences -Especially large transport planes

3.0% CO in Atmosphere = 35%COHgb in < 90 seconds

CO-Hgb Percentage



An Unconscious Landing

Plane Lands Itself in Hayfield as Pilot Slumbers

By Douglas R. Burnett

Dr. **Robert Frayser**, from Hoisington, Kan., had left his home airport at 7 am enroute for Topeka, Kan. "I was flying alone in my Comanche 400, cruising at 5,500 feet on autopilot, with the sun coming up on a clear, beautiful day." Everything was routine as he switched the fuel selector to the auxiliary tank and set up the navigation system for his destination.

After that, it was anything but routine. "Then, I lost about an hour and a half of my life." The plane, trimmed for cruise flight and on autopilot, flew a perfectly straight course over Kansas until it ran out of fuel and glided to a landing near Cairo, MO. When he awoke, confused, disoriented, and groggy from a deep sleep. As he became more oriented to his surroundings, he realized that he was now on the ground, in a hayfield. The engine was silent. The airplane's right wing was nearly torn off from an impact with a small tree, but the plane was otherwise intact. Frayser stated that there were **no early warnings or symptoms** to alert him. **"I just went to sleep**." Since the engine had stopped, no one heard the aircraft as it landed on the open field. "I was alone, disoriented, injured, and had a severe headache and ringing in my ears," he said.

What had caused him to fall asleep? It was **carbon monoxide** poisoning from a cracked manifold that apparently opened after the last annual inspection, was concealed by the heat shield and could not be detected during the pre-flight inspection. "The crack could have been there for a long time, just waiting for someone to turn on the heater," he said.

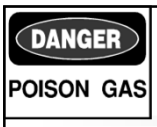
The Federal Air Surgeon's Medical Bulletin • Spring 1999

Nitrogen Oxides

- Major cause of workplace inhalation respiratory disease
  - ✈ Generated from burning Ni-containing compounds (celluloids, diesel fuel, wool fabrics, arc welding, electroplating, etc)
- Lower respiratory tract irritant (mild)
- ***NO*** inhibit alpha-1 protease inhibitors in the bronchioles
- Due to its mild odor and low tissue solubility little "warning signs" are present
- Symptoms of acute bronchitis/bronchiolitis typically appears 1-30 hours after the exposure

Sulfur Oxides

- Combustion of sulfur containing fossil fuels "Rotten eggs"
- Upper respiratory tract irritant
- Acute exposure symptoms:
  - ✈ mucous membrane & respiratory tract irritation
- Chronic exposure can lead to
  - ✈ chronic "bronchitis-like" airway disease characterized by hypertrophic mucous glands



Cyanides & Phosgene

- A product of thermal decomposition from:
  - Nylon, foam seats, plastics, wool, silk, synthetic rubber, paper, polymers
- Isocyanates are released from polymers and foams
- Phosgene can be produced from burning Fluorocarbon based aircraft electrical insulation"sweet corn/mowed hay"
  - Used in WW I & II as a chemical agent
  - Creates HCL acid when contacting moist surfaces
- Symptoms
  - Eye irritation, coughing, choking, wheezing, nausea

Solvents - Degreasers
(Various Types)

- Lipid-soluble solvents (Most neurologic impairment)
  - Aromatic hydrocarbons (Benzene, Tolulene)
  - Aliphatic hydrocarbons (*n*-Hexane)
  - Chlorinated hydrocarbons (Chloroform, TCE, TCA)
- Water-soluble solvents
  - Alcohols (Isopropanol, Ethylene glycol, De-Icing fluids)
  - Ketones (Acetone, MEK)
  - Esters (Ethyl acetate)
- Tolulene, 1,1,1 Trichloroethylene (TCE), 1,1,1 Trichloroethane (TCA) & Methyl-ethyl-ketone [MEK] are still all used in the military system.

Solvents - Degreasers

- All Solvents can produce a solvent-induced CNS effects due to its lipid solubility but can also cause:
  - Contact dermatitis
  - Vasodilatation with ETOH >>TCE induced "degreaser's flush"
  - Mucosal irritation of the eyes, nose, and throat
  - Impaired neuropsychologic performance to include
    - frequent headaches, memory problems, concentration, affective changes, fatigue, vertigo, and sleep problems
- What should we do when we run into a highly toxic substance workers deal with daily?
  - Substitution…...*d*-limonene (biodegradable citrus solvent FDA-GRAS)

Lubricants

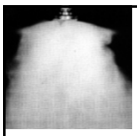
- Relatively non-toxic unless contaminated with PCBs
  - Used lubricants frequently contaminated with polymicrobial species (Gram -, Gram + and fungi)
- Oil induced dermatitis (allergic/irritant) common
- Respiratory exposure to oil mist can cause
  - chemical pneumonitis
  - irritation to eyes and lungs
  - headache, nausea and vomiting

Hydraulic Fluids

- Groups
  - Petroleum-based, Castor-oil based, Silicon-based, Phosphate ester-based
- Very common forms include
  - "Skydrol" and "Mil Spec 5560"
  - Dibutyl phenyl phosphate + tributyl phosphate
- Tricresyl phosphate
  - organophosphate-induced delayed neurotoxicity
  - "Nerve Agent-Like Activity"
- Known to cause dermatitis

Fire Extinguishing Agents

- Halogenated Hydrocarbons
- Carbon Dioxide
- AFFF Foam



Halon

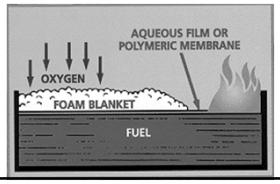
- Utilized in Automatic Fire-suppression system
- 1301 Halon determined by its chemical composition
  #C | #F | #CL| #Br
  1 3 0 1
- Hazards:
  - ✈ Expanding Gas
  - ✈ Simple Asphyxiant, displaces oxygen upon release
  - ✈ With exposure to flame will decompose to
    - HF, HCL, HBr, Phosgene analogues
  - ✈ Impulse Noise levels >160dB with activation
- Illegal in civilian sector
  - ✈ Ozone depletion

Carbon Dioxide ($CO^{2)}$

- Another simple Asphyxiant
- Initially mediates an immediate and uncontrolled hyperventilation response
- Danger most often in confined area
- As little as 10% CO^2 concentration can cause collapse, LOC, death

AFFF
"Aqueous Film Forming Foam"

- Found mainly around flight line, or anywhere fuel is stored
- Relatively nontoxic
- Protein based ("Soap Suds")



Toxic Metals & Fibers

Zinc
Chromium
Beryllium
Cadmium
Mag-Thorium
Depleted Uranium (DU)
Advanced Composites

DANGER

Metals

Toxic Metals

- Zn Zinc (Used in paint and plating)
  - ✈ Metal Fume Fever, chemical pneumonia
- Cr Chromium (Used in paint and plating)
  - ✈ "Chrome ulcers" of skin and "Chrome holes" of the nose
- Be Beryllium
  - ✈ Extremely toxic to lungs for 1-5% of the population exposed (through cell-mediated hypersensitivity)
  - ✈ Doesn't follow a normal Dose/Response curve
  - ✈ OH-58D (mast mounted IR scope), S-3 and other aircraft brake pads

DANGER

Heavy Metals

Toxic Metals

- Cd Cadmium (Used in batteries and electroplating)
  - ✈ Metal Fume Fever (flu -like symptoms)
  - ✈ Damages kidneys, lungs, liver, bones,
  - ✈ Lung, renal, and prostate cancer noted
- Th Mag-Thorium
  - ✈ Used in engine cowling
  - ✈ Radiation warnings not required until Thorium >4 %.
  - ✈ T-55 engine (Chinook, Huey, 58-C)

DANGER

Heavy Metals

Heavy Metals

- Depleted Uranium (Isotypes U-235 & U-238)
  - ✈ Used in High Kinetic Energy (KE) munitions and tank armor
    - 7.62 mm, .50 caliber, 20mm MK149 70, 25mm PGU-20 , 25mm M919 97 grams ,30mm PGU-14, 105mm M774 3364 grams - 7.41lbs. ,105mm M833 3668 grams - 8.08lbs, and various missile components
  - ✈ Primary hazard lies in its heavy metal nephrotoxicity more than its radiation hazard
    - Acute exposure can lead to acute tubular necrosis (ATN)
  - ✈ Retained fragments removed only if
    - the fragment is easily accessible
    - the fragment is over 1 cm in size
  - ✈ Since 1993, 33 vets involved in DU friendly fire incident are under VA monitoring for adverse effects.

Advanced Composite Materials

Are imbedded fibres in a resin

Examples:

- Graphite Epoxy
- Kevlar®
- Fiberglass
- Boron
- Nomex®

Why use ACMs?

- Strong
- Light weight
- Corrosion resistant
- Fewer parts
- New shapes
- Reduced radar signature

Advanced Composite Materials

Aircraft Utilization

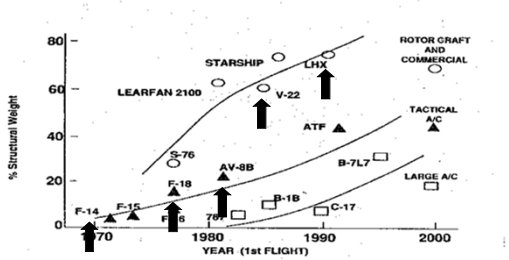


Figure 1. Current and projected advanced composites usage on aircraft.

Advanced Composite Materials

- Composites: fiber layers held in correct orientation with a binding resin
- Working, machining, or rough handling of these materials may cause airborne release particulate fibers (boron, graphite and fiberglass)
- Working/machining or during a mishap investigation heated composites may also release toxic epoxy resins fumes of hydrogen sulfide, carbon monoxide and cyanide

Health Concerns of ACMs

- Chemical release in a fire
- Fiber threat (inhalation)
- Mechanical following a crash
- Aerosolization of chemicals
- TLVs
  - ✈ MDA 0.1 ppm
  - ✈ Graphite fibres 10 mg/m^3

ACM Injury Prevention

- Avoid skin contact
- Develop procedures for handling specific composites
- Immediate Response Team:
  - ✈ gloves
  - ✈ masks
  - ✈ coveralls (Tyvek®)
  - ✈ goggles

Noise & Vibration

- Most common problem in the aviation worksite
  - ✈ Majority of work is in an environment greater than 85dB
  - ✈ FS must continually look for ways to limit noise exposure
    - Reduce the source of noise exposure
    - Look for ways to shield the source of noise exposure
  - ✈ Hearing conservation program (when engineering controls fails)
    - Must watch for Audiogram dB losses at the 4-5 Khz range
    - Educate and enforce use of hearing protection devices
      - ensure proper fitting helmet/cranial with foam ear plugs
      - US Army uses CEP's when available (**C**ommunication **E**ar **P**lug)
    - When repeat Audiograms reveals STS, need to consider job change

Incidence of Personnel Significant Threshold Shifts

Onboard 154 East Coast Naval Vessels

Job Specialty/Rank	Incidence of STS (%)
Airman Apprentice	70.2
Damage Control	57
Sonar Technician	48
Fireman	40.1
Engineman	18
Aviation Machinist Mate	24.1
Gas Turbine Technician	20.1
Hospital Corpsman	13.1

Wolgemuth & Luttrell, Military Medicine Vol.160, May 1995, pages 216-222

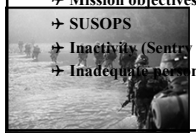
Climatic Conditions

Cold issues

- Physiologic Factors
  - ✈ Nutrition/ hydration
  - ✈ Fatigue/illness
  - ✈ ETOH/tobacco use
- Risk Factors
  - ✈ **Temperature, wind, wetness**
  - ✈ **Mission objectives**
  - ✈ **SUSOPS**
  - ✈ **Inactivity (Sentry Duty)**
  - ✈ **Inadequate personnel training**

Hot issues

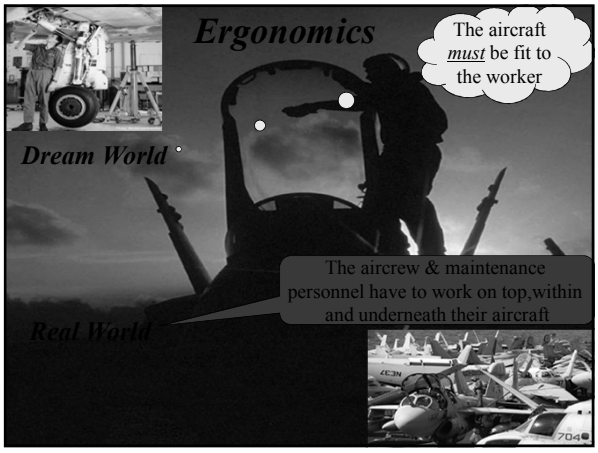
- WBGT best estimate of heat stress
  - ✈ Underestimates the heat stress in highly humid environments
- Acclimatization requires
  - ✈ Time "in-country" (> 4-8 days)
  - ✈ Daily heat exposure (> 100"/day)
- Decreased heat acclimatization
  - ✈ Dehydration
  - ✈ Concurrent illness
  - ✈ Sleep deprivation
  - ✈ Any skin diseases
  - ✈ Physically unfit



Radiation

(Ionizing & Non-Ionizing)

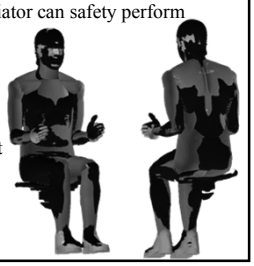
- Ionizing Radiation
  - ✈ Depleted Uranium rounds used in Hi-KE ammunitions
- Non-Ionizing Radiation
  - ✈ Ultra-violet
    - Cataract risk and skin burns/cancer
  - ✈ Infra-red
    - Cataract or corneal burn risk and skin burns
  - ✈ Lasers
    - Correct eye protection for the frequency of Laser
  - ✈ Microwave
    - Radar emission from EA6B, CVN flight decks, ovens



Ergonomics

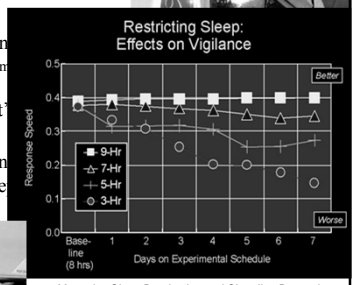
The Flight Surgeon needs to be comfortable with the performance of cockpit evaluations to ensure the aviator can safety perform his duties.

- ✈ Functional reach/leg length
- ✈ Sitting height
- ✈ Body weight & physical strength requirements to operate the aircraft



Work Schedules / Sleep Deprivation

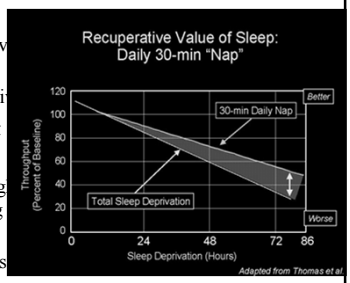
- Sleep deprivation will always degrade performan
  - ✈ Watch out for circadian rhythm disturbances
- Closely monitor your unit' work/rest cycles
- Attempt to make importan decision-making after slee period.



Managing Sleep Deprivation and Circadian Desynchrony
Walter Reed Dept of Neurobiology and behavior
Nancy Jo Westensten, Ph.D.

Work Schedules / Sleep Deprivation

- Strategic naps **will** improv performance
- Several naps can be additi
- Resting/Dosing is **not** restorative
- Keep day workers and nig workers in separate living spaces
- Avoid use stimulant drugs
  - ✈ Could be useful with extremely short (<48hrs) mission.



Managing Sleep Deprivation and Circadian Desynchrony
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General Protective Measures on the Flightline....

- Keep current on the hazardous materials within ***your*** flightline.
- Continually provide formal and informal briefings to your crews regarding personal protective equipment and health hazards around the flightline
- Keep your head on a swivel - always be on the lookout for a wave of stupidity or carelessness.

Be Aware & Be Informed!

Thank you

Questions?