The Regulatory Implications of Bleed Air Supply Contamination

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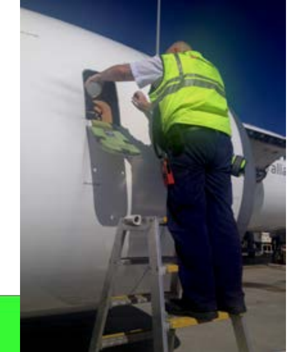
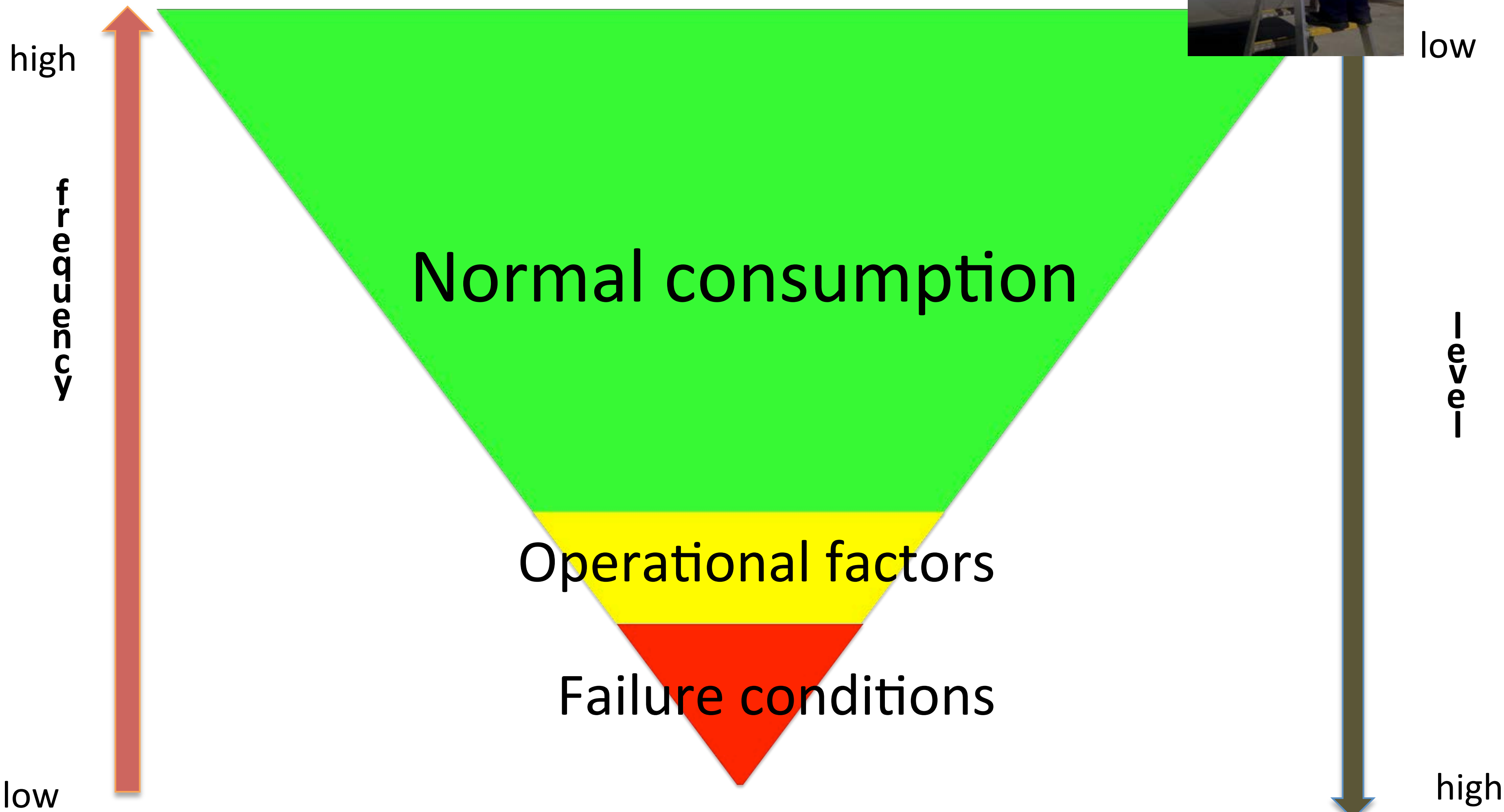
Oil consumption





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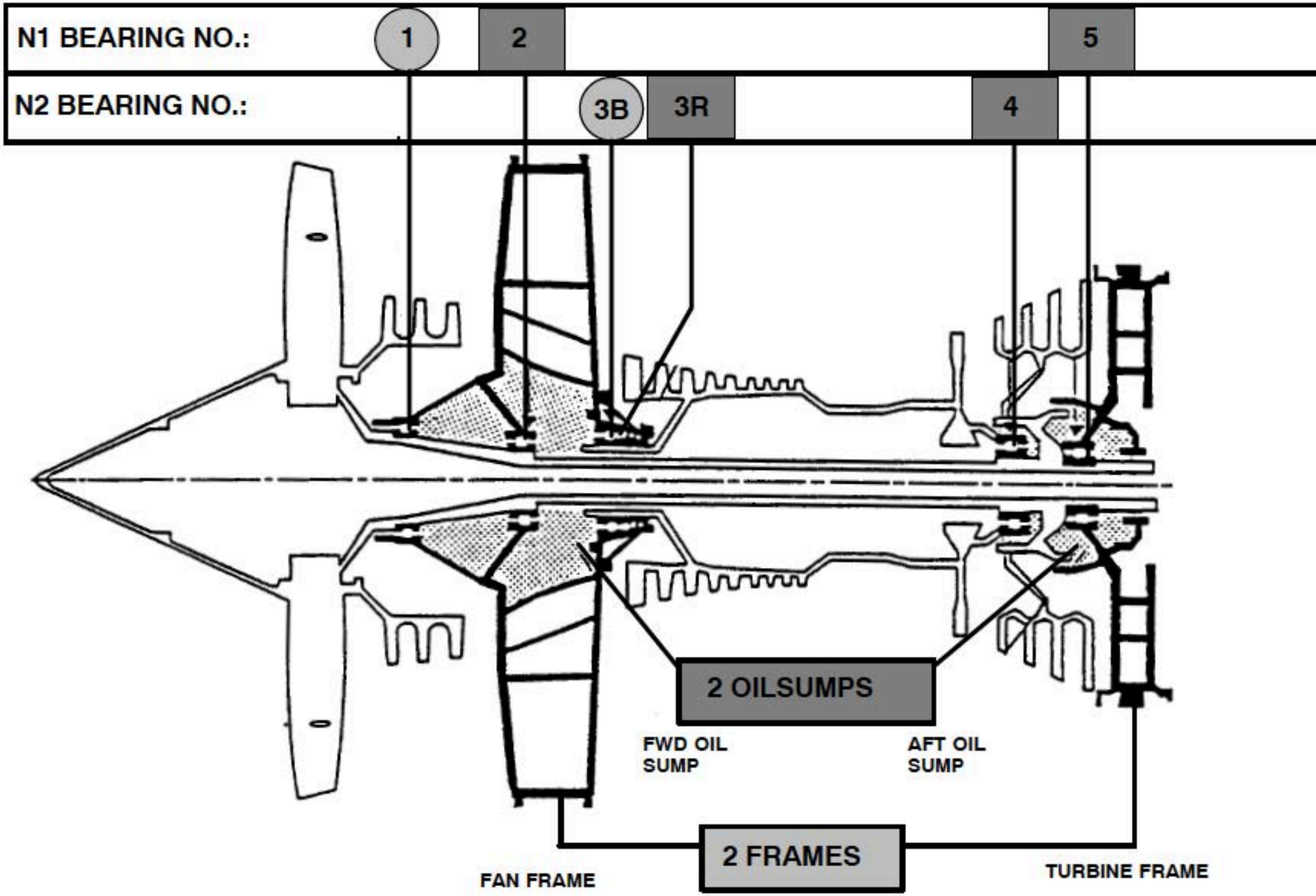
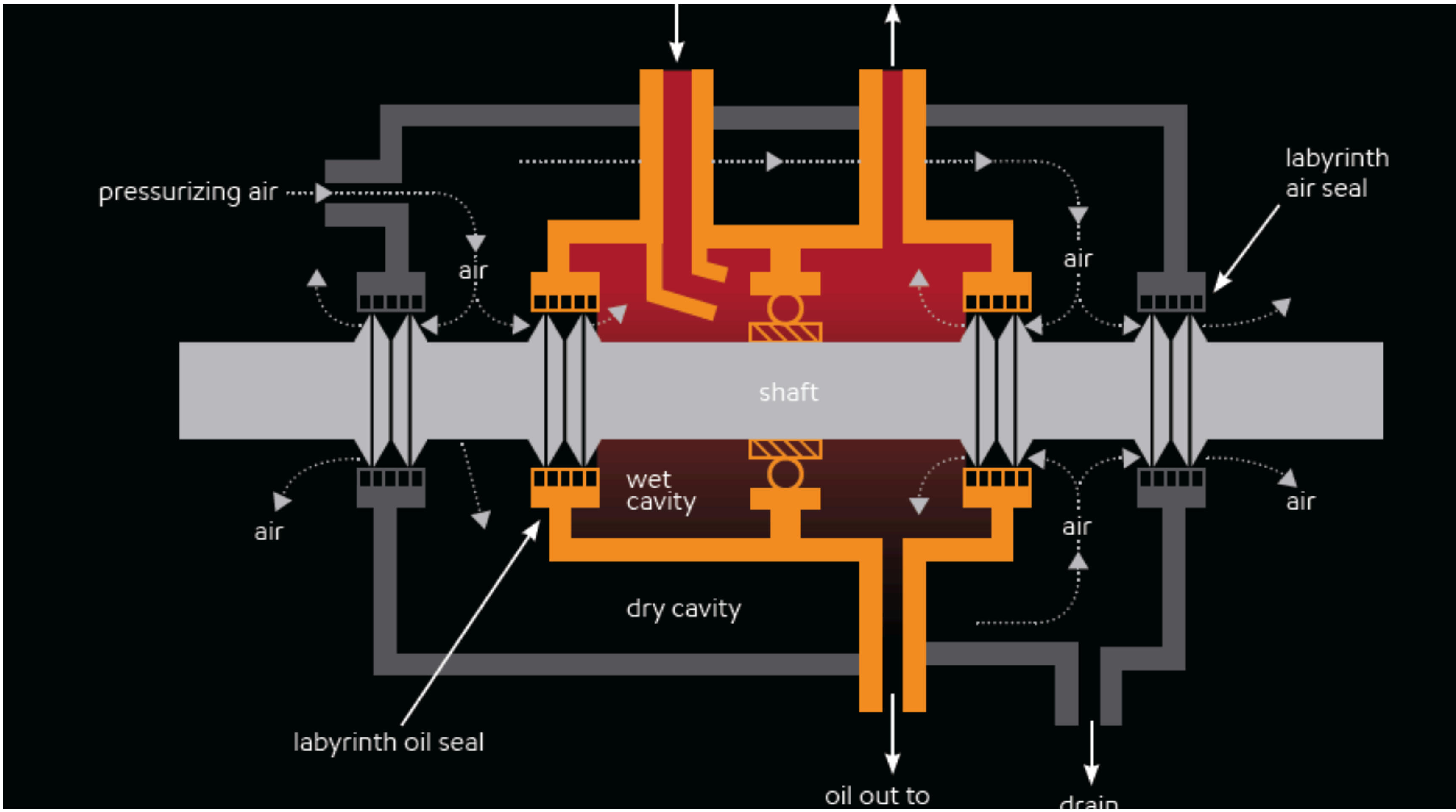


Figure 11 Engine Construction

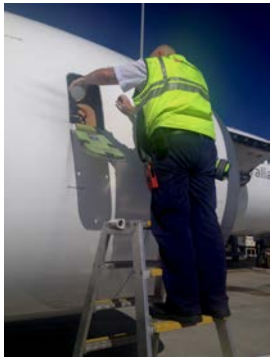
Lufthansa (1999)https://www.metabunk.org/attachments/docslide-us_a-320-engine-pdf.16733

Oil bearing chamber



https://www.exxonmobil.com/en/aviation/knowledge-library/resources/jet-engine-oil-system-2

Normal oil consumption

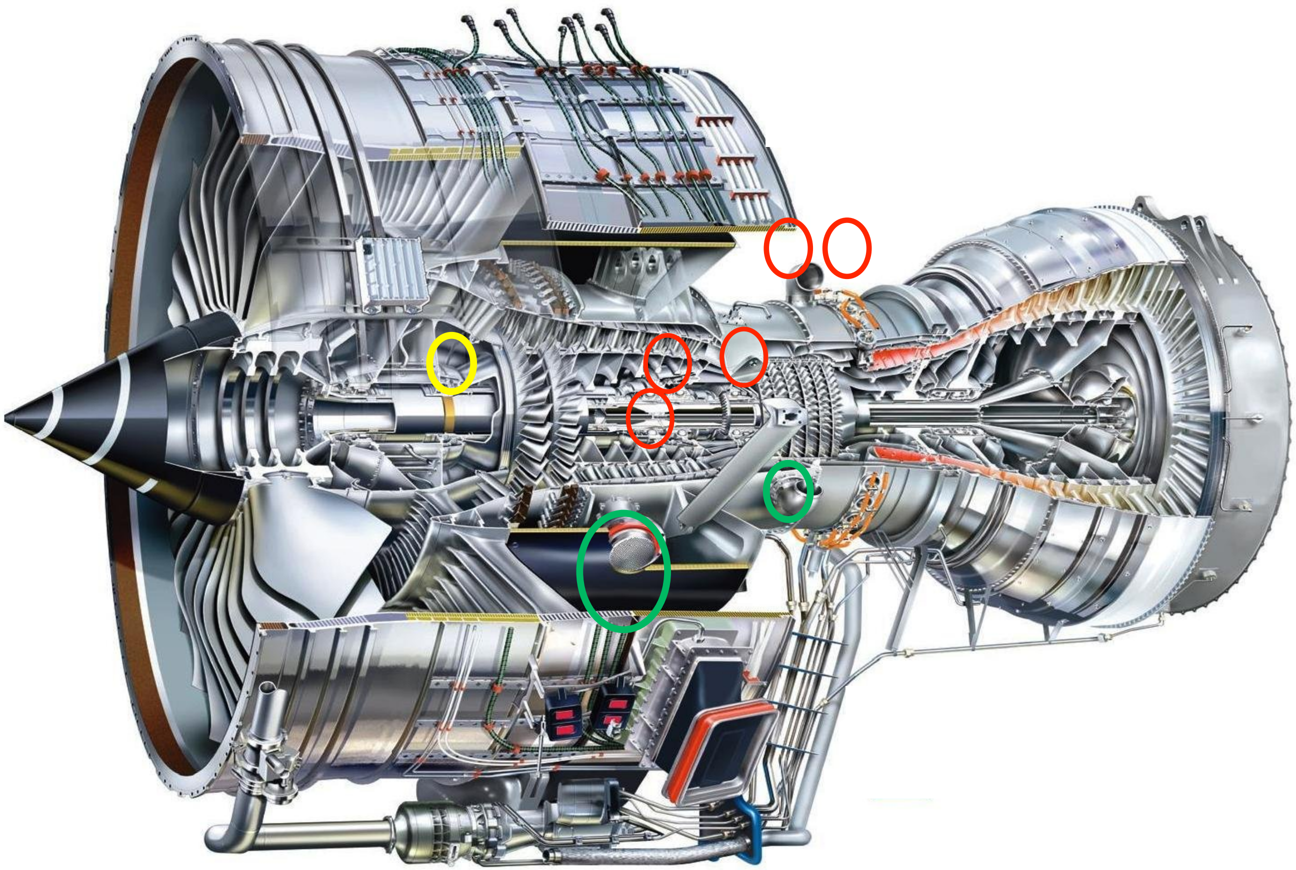


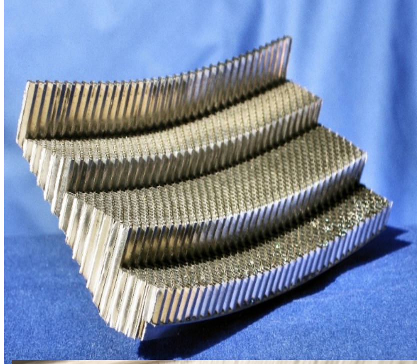
- Normal “permissible” oil consumption via:
  - Breather/deoiler - vent system
  - past seals → core airflow
  - Oil leaks
- Rate of loss affected by various factors
  - Style of seal, balance ratio, Lubricating regime, operating conditions (speed, temp, pressures), component condition, wear life, distortion…

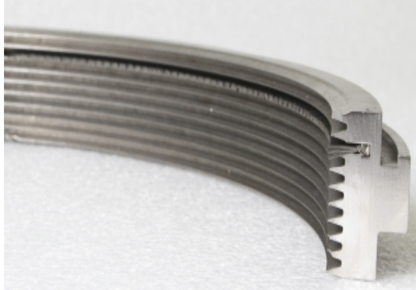
All dynamic seals are designed to leak

https://www.exxonmobil.com/en/aviation/knowledge-library/resources/categories/tech-topics
https://gavinpublishers.com/admin/assets/articles_pdf/1537165462new_article_pdf69025564.pdf

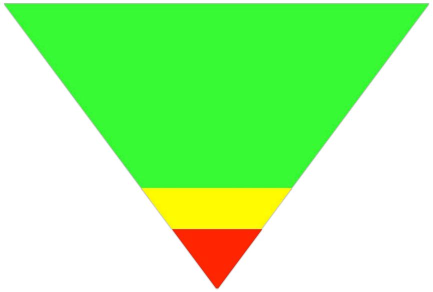
Seals and bearings / Air off-take







Oil leaks



1. Normal operations

- All dynamic seals leak very low levels (not absolute design)
  - Rely on pressurised air: seals have a clearance / lubricated surface
- Increased leakage:
  - Pressure changes (transients) → Power air supply config changes
  - Thermal mechanical changes in engine
  - Low internal pressure – e.g. start up, taxiing, descent
  - Oil hydrolysis (reaction with water) and thermal oxidation → release of carboxylic acids which <u>can escape</u> from oil system (associated with strong odour "dirty sock")

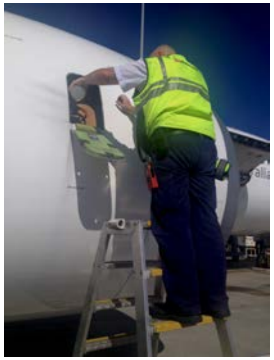
2. Operational: e.g. wearing seal; oil overfill
3. Failure conditions: bearing seal failure or component…

Misconceptions about oil leakage

1. Higher pressure in gas path than inside bearing chamber – Keeps oil in bearing chamber ✗
2. Seals only leak when failure occurs ✗
3. Reverse pressures to be avoided – prevents leakage ✗

Sealing bearing chambers at near ambient pressure is difficult – Chupp 2006
NASA/TM—2006-214341

Recognition of oil leakage in normal conditions



- Oil replenishment ('top up') maintains oil additives (Johnson 2018)
- Oils designed to work in engine, <u>limiting</u> exposure (ExxonMobil, 2018)
- Bleed system pressure fluctuations cause bearing seals to leak allowing oil to migrate into the cabin bleed air (ExxonMobil, 2018)
- "Shaft seals- must function as SEALS - NOT flow restrictors" (Bill, 1991)
- "A zero seal leakage is an oxymoron" – (Chupp, 2006)
- Most engines might have a certain low level turbine oil leak rate (permanent oil entries) – (EASA 2017)

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Regulatory implications

FAA

- Regulations
- Acceptable means of compliance: e.g. Advisory circulars (AC)

EASA

- Regulations – Basic / implementing (Hard law)

Soft Law - non binding

- Certification Standards (CS)
- Acceptable means of compliance (AMC)
- Guidance material

Two ways of addressing this problem

1. Engineering failure analysis – Currently used
   – Analysis, ground flight testing or simulator tests
   – Engineering judgement, previous experience, sound design & test philosophies.

2. Thorough assessment of the system in use in both normal and failure modes.

Do not place reliance on reporting system due acknowledged under-reporting

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Method 1 - brief outline of regulations, standards & AMC

- 25.831- air does not cause undue discomfort, harm.
- 25.1309 & AMC
  - System works as intended
  - Air supply system does not cause impaired crew efficiency/ discomfort > 1 in 100,000 flight hours.
- CS-E/APU… Engine/APU & AMC safety analysis
  - Oil… in bleed air does not degrade crew performance > 1 in 100,000 engine/APU hours

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Method 2 – assessment of whole system

- Oil leaks at low levels in normal operations- permissible oil consumption- *see previous*
- Oils and other hazardous substances enter the bleed air – *see next*

Oils cause adverse effects

- Oil MSDS/labels:
- Global chemical hazards system / e.g. EU classification *hazardous substances databases
  - *Oils: Damage to unborn/fertility; damage to organs (single repeat exposures): skin, respiratory sensitization; eye, respiratory, skin irritation; harmful in contact with skin; eye damage
  - * Hydraulic/deicing fluids: Above + harmful if inhaled; genetic effects; suspected to cause cancer; drowsiness, dizziness
- Manufacturers recognizes adverse effects, hazards,
  - Shell (1999); Boeing (2007); ExxonMobil (2017), Rolls Royce (2003)…
- Reports (where available) show Acute (short-term) effects/ impairment at > ~ 30%

ExxonMobil

Product Name: MOBIL JET OIL II
Revision Date: 06 Sep 2017
Page 1 of 11

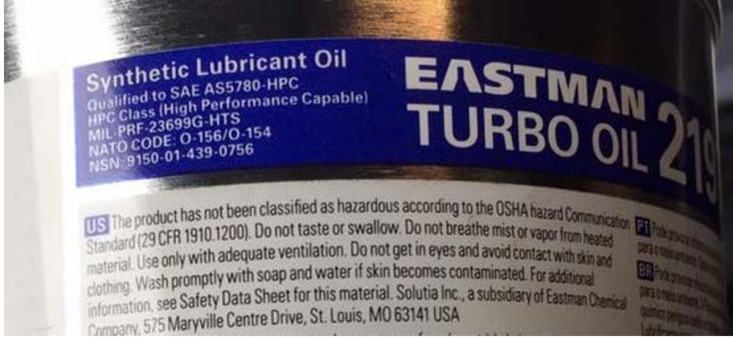
SAFETY DATA SHEET

SECTION 1	PRODUCT AND COMPANY IDENTIFICATION

PRODUCT

Product Name: MOBIL JET OIL II
Product Description: Synthetic Esters and Additives
Product Code: 201550101020, 430207-00, 970570
Intended Use: Aviation lubricating oil, Turbine oil

oils



Mobil Jet Oil II

- May cause damage to organs through prolonged or repeated exposure. (Blood, Kidney); suspected to damage fertility;
- Symptoms of acute exposure to decomposition products: headache; nausea; eye nose & throat irritation;
- Not expected under normal conditions of use.

Eastman 2197

- Do not breathe mist or vapor from heated material;
- Inhalation of thermal decomposition products may lead to adverse effects;

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Oils are hazardous

- *"Jet oils do not pose a hazard when used as intended… Mobil jet oils are intended to be used in the lubrication of engine oil systems"*- (ExxonMobil 2018)
- *"We do not believe that Mobil jet turbine oils pose any significant toxicological risk to individuals* *accidentally* *exposed to aerosols or vapors in aircraft cabins. Such exposures are not what we would refer to as "normal use"* (Mobil, Australian Senate Inquiry, 1999/2000)
- *"Ortho –TCP is a known hazard; but exposure is controlled."* - (ExxonMobil 2018)
- *"Oil leaking from an engine entering the customer off-take is "classified as HAZARDOUS""* (Rolls Royce 2003)
- *"Oil vapors and coking smells are obnoxious at best and health hazards at worst to the customer"* (NASA, 1995)

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Where are we up to?

- Design guarantees low levels of oil in normal operation – all flights
  - Confirmed by many cabin air quality studies over 20 years+ / swab tests, ducting…

So does this design meet the airworthiness standards?

NICE… X Lets have a further look

London to Nice

Regulation - Impairment not > 1 per 100,000 flight hours

- e.g. London to Nice - 2 hours

Regulatory approach: impaired efficiency/degraded performance should not be occurring > 1 in 50,000 London to Nice flights.

Reality ?

Are the regulations/standards & AMC being met?

1. **25.831 – ventilation air**

   a) There must be a sufficient uncontaminated ‘fresh” air to enable crew to perform duties without undue discomfort/ fatigue

   b) Air must be free of harmful / hazardous concentrations of gasses and vapours

Are the regulations/standards & AMC being met?

1. **25.831 – ventilation air**

Is there enough uncontaminated air to not cause undue discomfort – **NO**

Is air free of concentrations of gasses/vapours causing harm – **NO**

Adverse/ harmful effects are expected and being routinely documented

Are the regulations/standards & AMC being met?

2. 25.1309 & AMC – Equipment systems…design requirements

- Do the systems and equipment perform intended function under foreseeable operating conditions?
- 'Major' failure conditions must be- remote* (CS) - *Unlikely to occur in each aircraft during total life, but may occur several times during life of an number of aircraft.
- Impaired crew efficiency/ discomfort to pilots must not occur more than 1 per 100,000 flight hours (10^{-5}- 10^{-7}) (AMC)

Oil leakage is a 'probable' & above or Expected condition

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Are the regulations/standards & AMC being met?

2. 25.1309 – equipment systems… design requirements

- NO: Oil from the engine lubrication system enters the bleed air (not intended purpose) under foreseeable conditions
- NO: Impairment ('Major' failure) to crew efficiency is occurring > than 1 in 100,000 flight hours
- NO: oil leakage into the bleed air supply will occur to all aircraft =

✈'Oil leakage is probable' & **expected condition**

'Permissible oil consumption'

Are the regulations/standards & AMC being met?

3. Engine/APU - CS E -510 / FAR 33.75 & APU & AMC…- Failure/ safety analysis

- Hazardous engine effects must be 'extremely remote' occurring less than 1 in 10 million / engine hours (10^{-7}) (CS)
  - Includes toxic products in bleed air sufficient to incapacitate crew/pax (CS)
- Major engine effects must be – 'remote' occurring less than 1 in 100,000/engine hours (10^{-5}) (CS)
  - Toxic products in bleed air sufficient to degrade crew performance (AMC)
  - Toxic products include degradation of oil leaking into compressor airflow (AMC)

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Are the regulations/standards & AMC being met?

3. **CS E 510 & AMC & CS APU 210 & AMC**… **Failure analysis**…

- **NO:** Degraded crew performance ('Major' engine/APU effects) due to oil leakage into compressor airflow/bleed air for cabin is occurring at > 1 in 100,000 engine/APU hours

✈'Oil leakage is probable' & **expected condition**

'Permissible oil consumption'

Other regulations/standards not being met

- FAR/CS 25.1309C - Information concerning unsafe system operating conditions must be provided to the crew to enable them to take appropriate corrective action – Warning system
- Unsafe condition – events occur more frequently than safety objectives allow that may impair crew efficiency, cause discomfort to occupants…
- Bleed air purity testing

Certification - Michaelis MSc (2016)

- Certification: Must show compliance with all requirements
  - No requirement to follow a specific process
  - Interactive process between regulator and manufacturers
- Engine/APU: Focus on 'hazardous' engine effects − concentration of toxic products sufficient to incapacitate − Not AMC
- Airframe: No requirement for the air to be pristine free of contaminants (FAA); CO, CO2,O3, enough fresh air…
  - Manufacturers can choose to follow additional standards: e.g. ASHRAE, ASD-STAN (cancelled), SAE guidelines, NIOSH, CDC…

✈ Process is insufficient to ensure to ensure breathing air (bleed air) will not lead to impaired crew efficiency & degraded performance and adverse effects to occupants.

✈ There is a gap between the bleed air system regulatory process and the supply of clean air in aircraft. (Michaelis, 2016)

✈ Non binding

✈ Focus on <u>failure</u> conditions

Is this a safety issue? The EASA way!

The mini-BACS installation at RIVM, NL

BACS build-up within safety fence

Where to next?

- Future designs should be bleed-free;
- Air cleaning technology (filtration, catalytic convertors) to be provided for supply air (bleed and non bleed aircraft);
- Sensors to be fitted;
- Better designs: seals, improved oil reservoir, other design features;
- Improved clean air regulations/standards & compliance;
- Understanding low-level oil leakage occurs in normal operations, not just failure scenarios;
- Better procedures, training, education: crew, maintenance & management;
- Frequency seen in terms of <u>design</u>, NOT reporting.

Thank you

Further information:

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