Bearing Chamber Sealing And The Use of Aircraft Bleed Air

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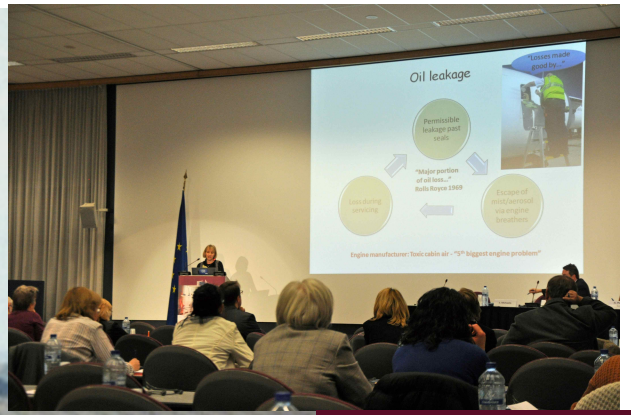
Who am I?



Health and Flight Safety Implications from Exposure to Contaminated Air in Aircraft

PhD
S. Michaelis
2010

) - http://handle.unsw.edu.au/1959.4/50342

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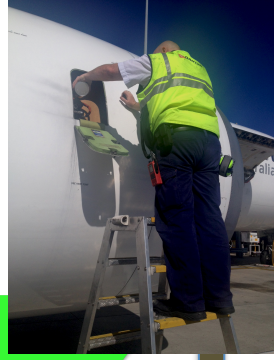
Oil consumption



high

low

frequency

level

Normal consumption

Operational factors

Failure conditions

low

high

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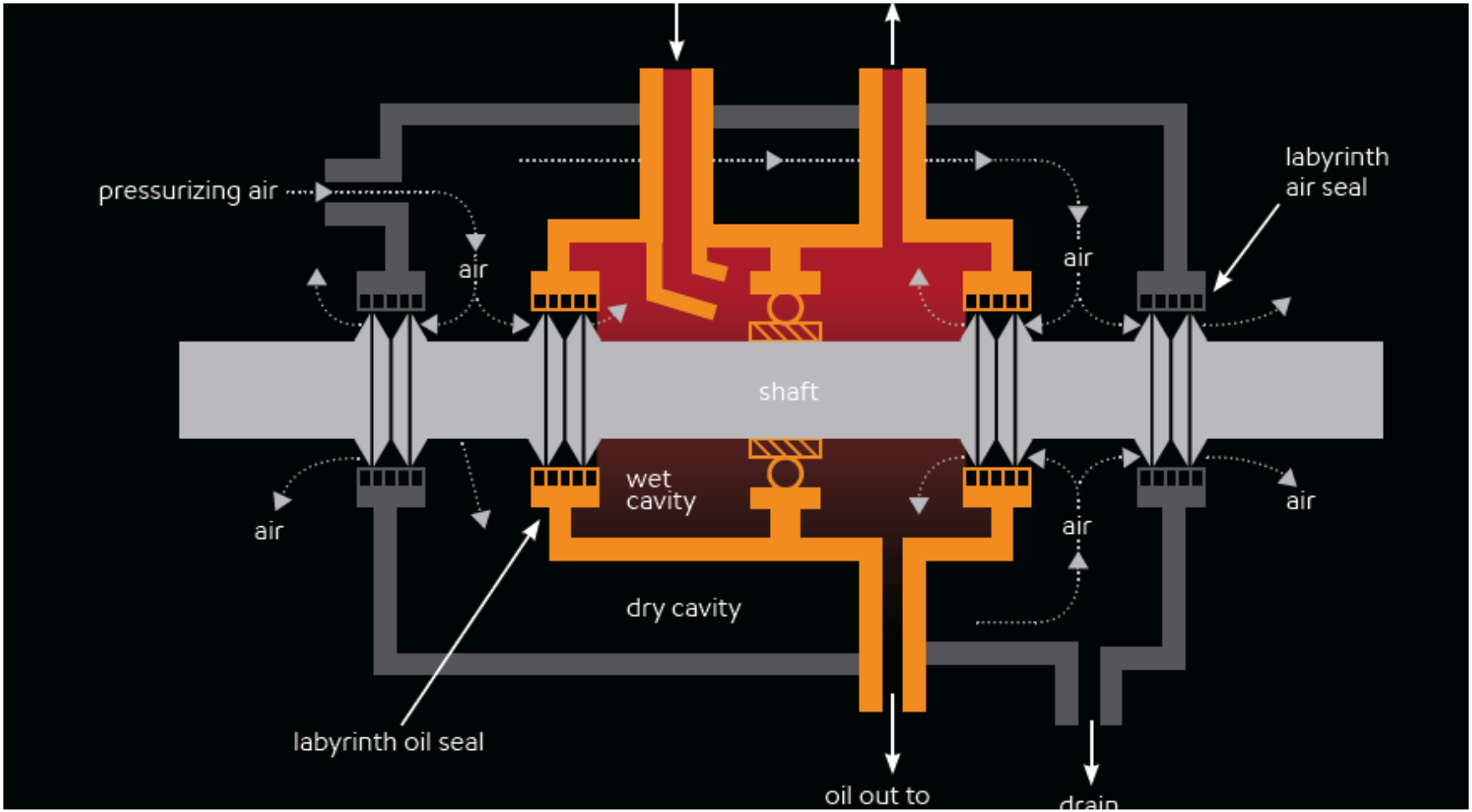
Oil bearing chamber



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

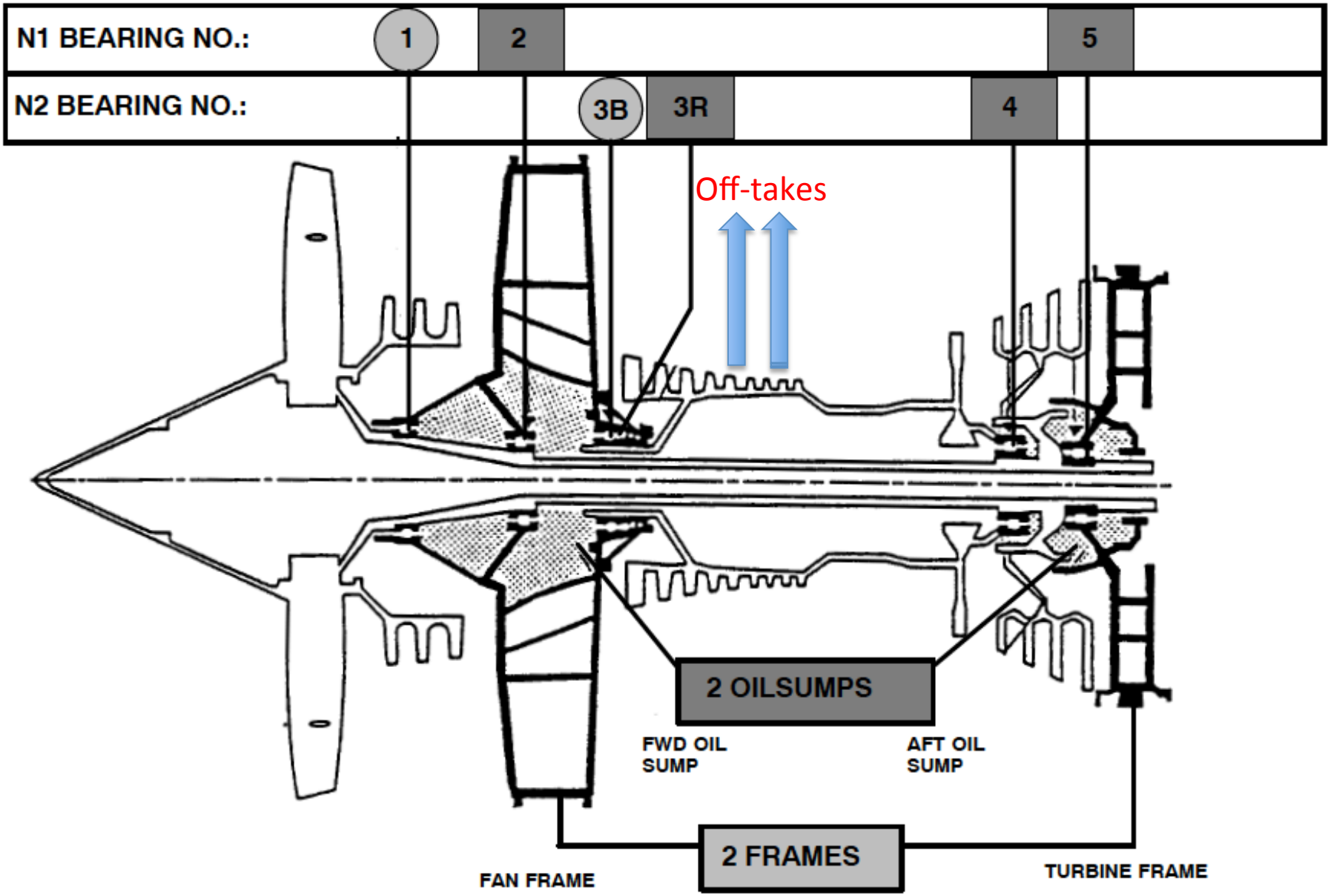
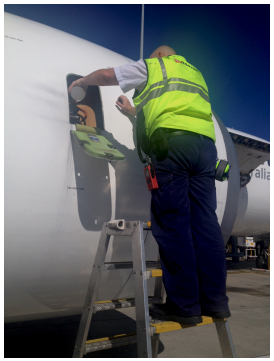


Figure 11 Engine Construction

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

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…

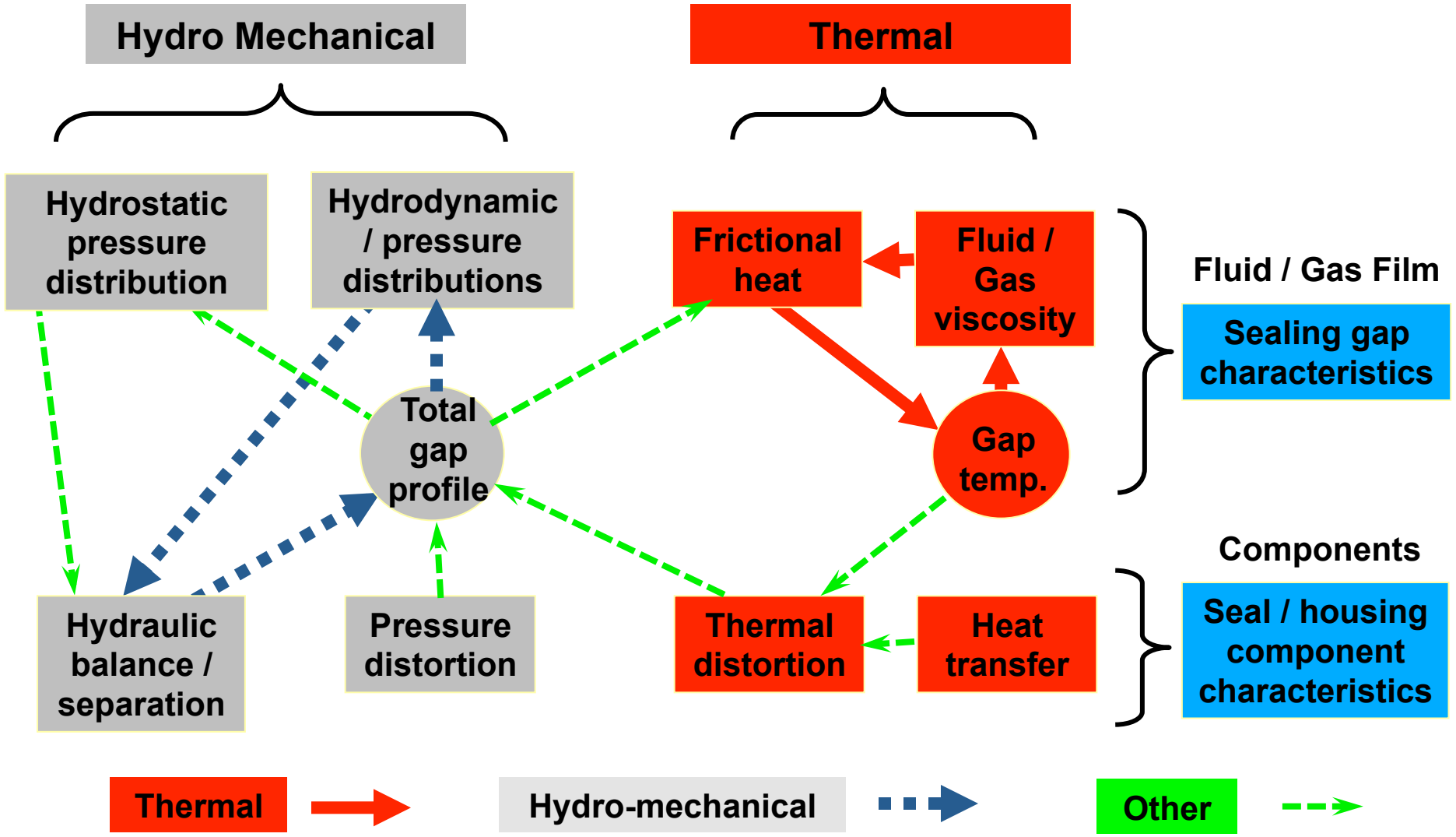


All dynamic seals are designed to leak

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

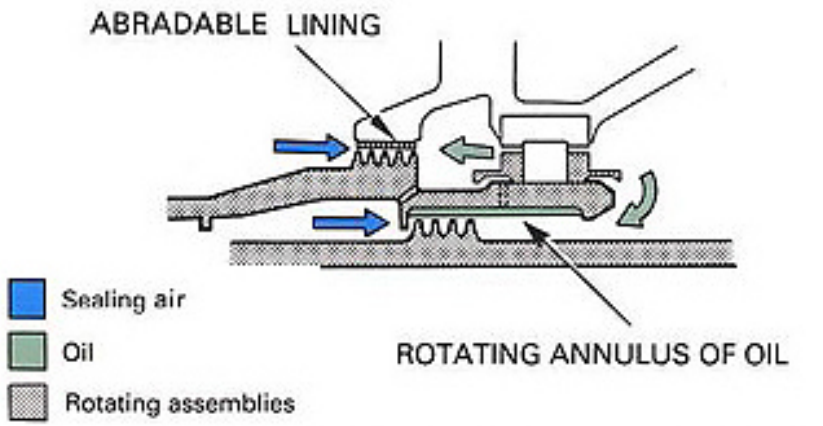
FACTORS AFFECTING SEALS

- Seal leakage concepts



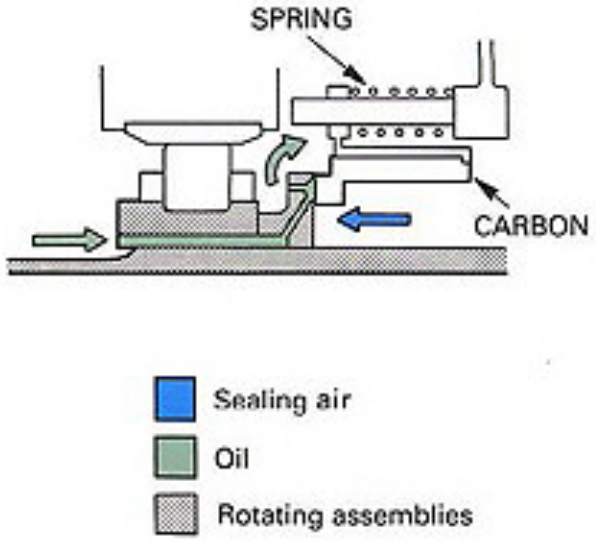
Typical seals

Labyrinth seal



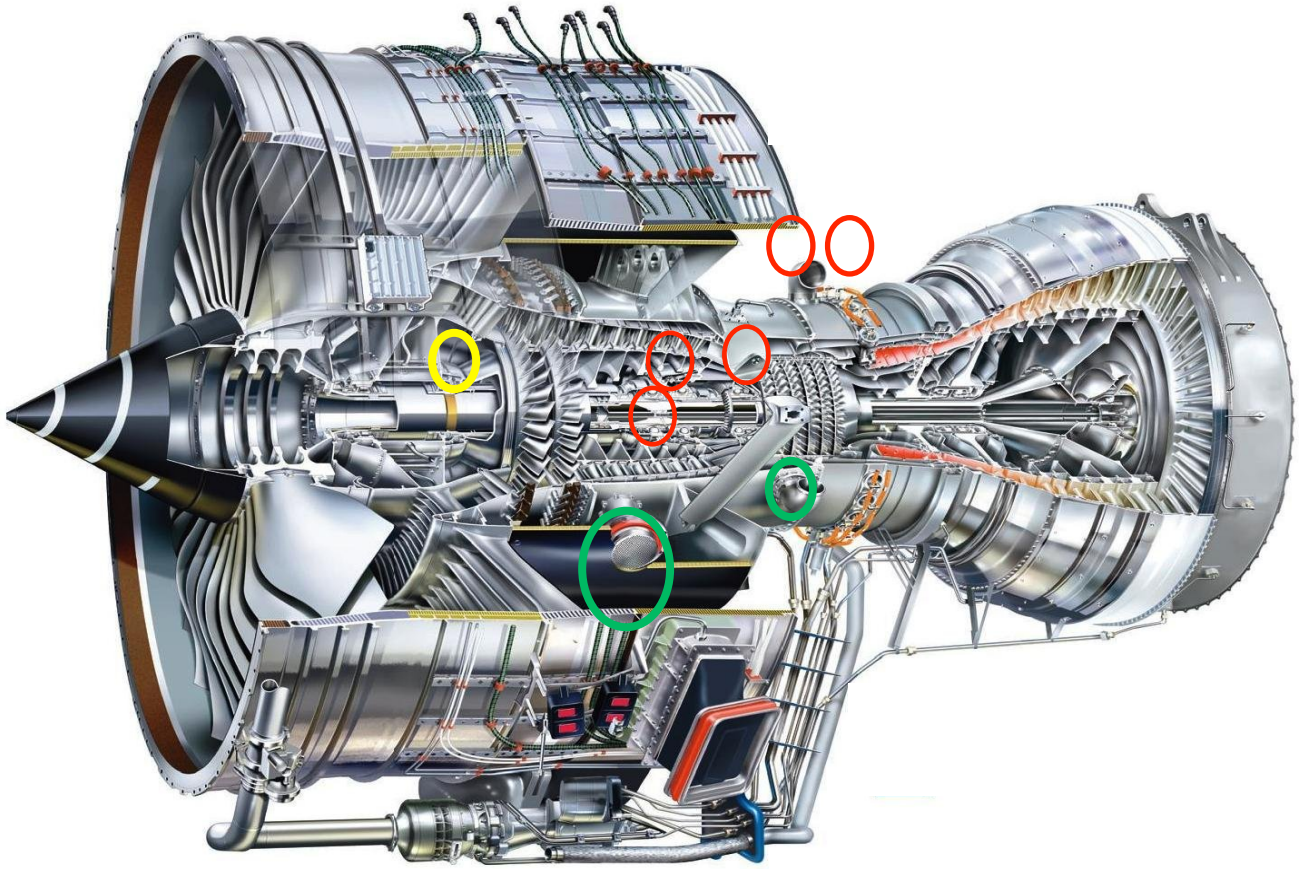
FLUID AND ABRADABLE LINED LABYRINTH SEAL

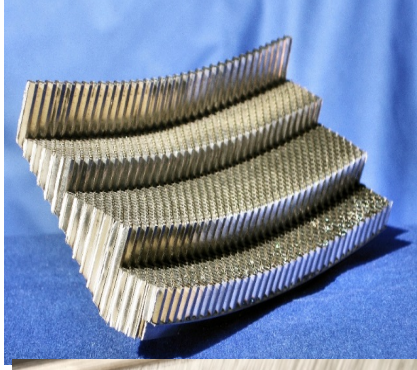
Mechanical/ Carbon seal

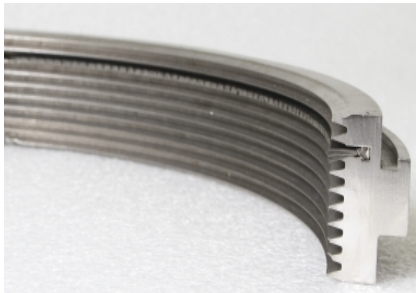


CARBON SEAL

Seals and bearings / Air off-take







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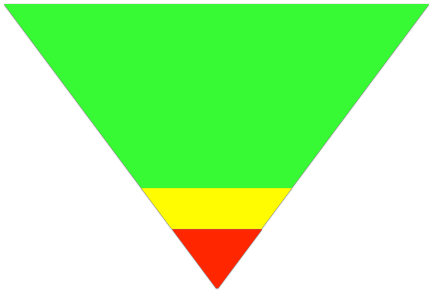
Oil leaks – 3 ways



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 can escape 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 – Ch

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, limiting 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)

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

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

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%

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oils

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

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: <u>headache; nausea; eye nose & throat irritation</u>;
- Not expected under normal conditions of use. *(engine)*

Eastman 2197

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

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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 ?

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Are the regulations/standards & AMC being met?

1. 25.831 – ventilation air

Is there sufficient uncontaminated ‘fresh” air to enable crew to perform duties without undue discomfort/fatigue? – **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? **No**
- Are 'Major' failure conditions remote*? (CS) - *Unlikely to occur in each aircraft during total life, but may occur several times during life of an number of aircraft. **NO**
- Does impaired crew efficiency/ discomfort to pilots occur less than 1 per 100,000 flight hours (10^{-5}- 10^{-7}) (AMC)? **NO**

Oil leakage is a 'probable' & above or 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

- Are 'Hazardous' engine effects 'extremely remote' occurring less than 1 in 10 million / engine hours (10^{-7}) (CS)? - **? No**
  - Includes toxic products in bleed air sufficient to incapacitate crew/pax (CS)
- Are 'Major' engine effects 'remote' -occurring less than 1 in 100,000/engine hours (10^{-5}) (CS) ? - **NO**
  - Toxic products in bleed air sufficient to degrade crew performance (AMC)
  - Toxic products include degradation of oil leaking into compressor airflow/ bleed air (AMC)
    - ✈'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, SAE, ASD-STAN **X**

- Process is insufficient to ensure to ensure breathing air (bleed air) will not lead to impaired crew efficiency / degraded performance / adverse effects to occupants.
- There is a gap between the bleed air system regulatory process and the supply of clean air in aircraft. - **NOT AIRWORTHY!** (Michaelis, 2016)
- Non binding
- Focus on failure 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 design, NOT reporting.

Thank you

Further information:

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