Aircraft Cabin Air Contamination -
Health & Flight Safety Implications

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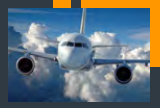
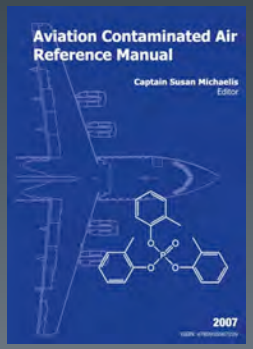
Lecture for the German Aerospace Society (DGLR), German Engineering Society (VDI),
Royal Aeronautical Society Hamburg Branch (RAeS) and
Hamburg University of Applied Sciences (HAW Hamburg)
HAW Hamburg, 08/11/12

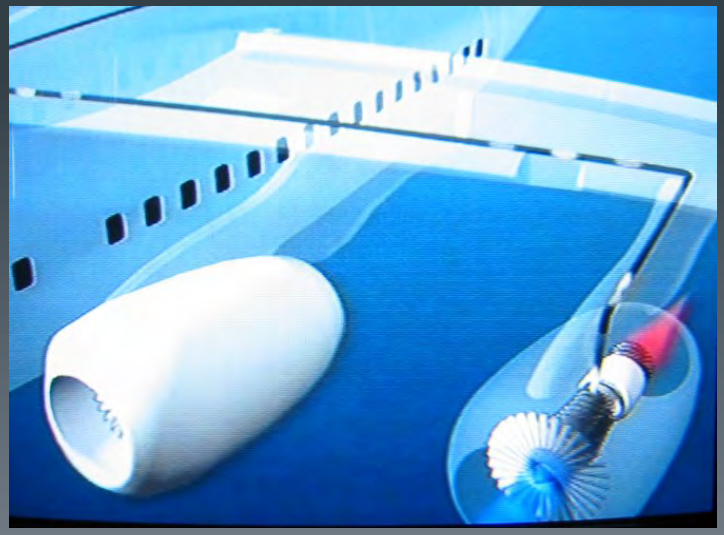
My Background



- Australian ATPL pilot (1986-1997)
- PhD (2010) - Safety Science (aviation), University Of New South Wales, Australia – "Health & flight safety implications from exposure to contaminated air in aircraft" -ISBN: 978-0-95-554377-7
- Aviation Health & Safety Consultant /OH&S consultant
- Head of Research Global Cabin Air Quality Executive (GCAQE.org)
- NEBOSH; COSHH; IOSH
- Author - Aviation Contaminated Air reference Manual: 2007 (ACARM)
- Briefed industry, Governments, military, unions… on health & flight safety implications of CAQ for over 15 years



What is the Problem?



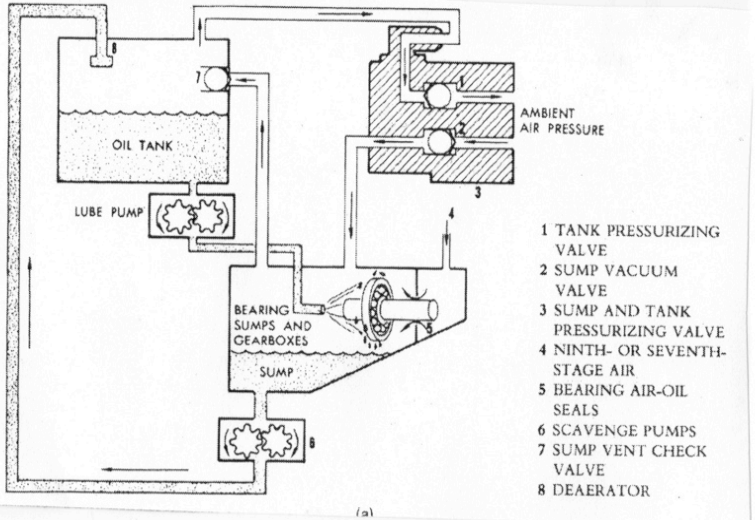
What is the Problem?

- Oil used for cooling, lubrication, sealing…
- Pressurized seals are used to prevent oil leakage from bearing chambers
- Oil leakage kept to minimum by pressurizing bearing sump with compressor bleed air; (seal leakage air)
- Seal leakage air is a performance/cost penalty
- Oil leakage into compressor & cabin air off-take – Degraded air quality (“dirty sock odour”)

Oil leaks as a function of design, operation (wear, clearances), maintenance (failure)

What is the Problem?

Engines leaking oil into air supply



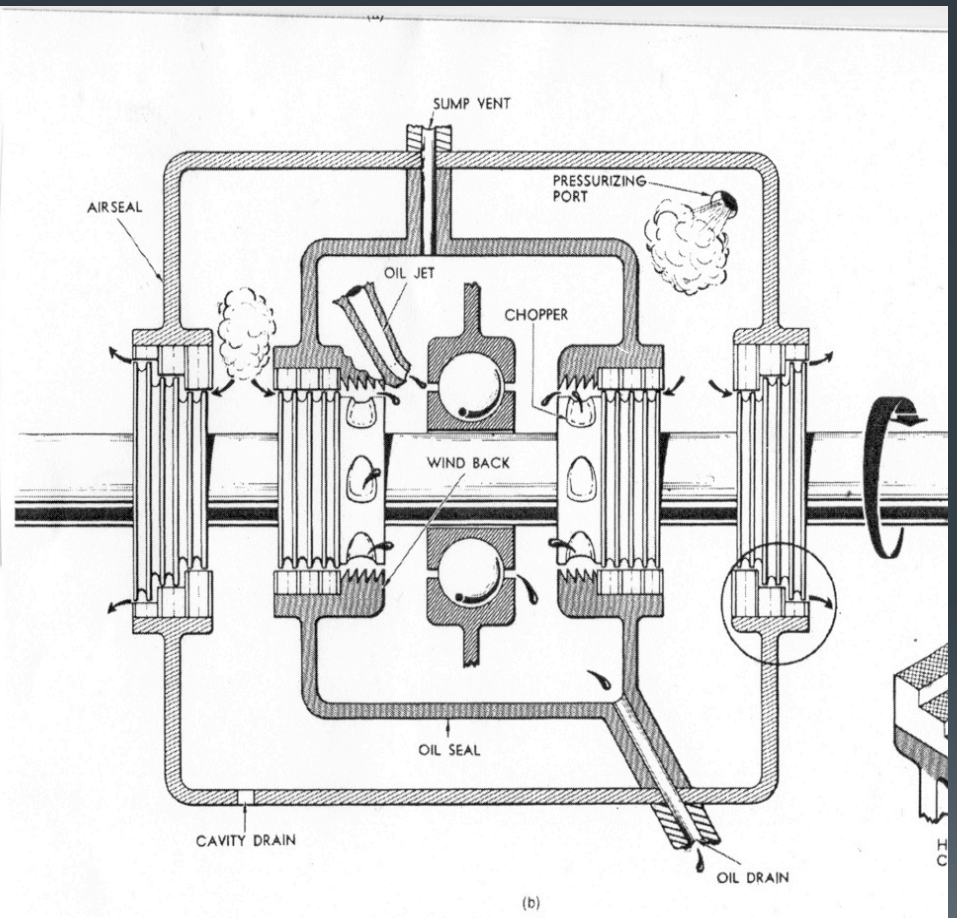


FIG. 15-9 (a) A simplified diagram of a tank and sump pressurizing system. (b) The sump sealing system used on the General Electric CF6 high-bypass-ratio turbofan engine.

What is the Problem?

- Pressure drop theoretically keeps oil inside bearing chamber but not occurring in practice
- Air / oil vented from chambers with air vented overboard (oil?)
- Sealing factors are critical (clearances /wear/ compatibility…)
- Coking, carbon & sludge deposits, foaming, oxidation of oil
- Sealing may not be fully efficient at various stages of operation: e.g.: start-up, transient power changes…

Oil leaks as a function of design, operation (wear, clearances), maintenance (failure)

What is the Problem?

Engine Contribution to Safety

- Main engine threats:
  - High energy non-containment
  - Uncontrolled fire
  - Separation of engine/powerplant components
  - Major loss of thrust control
  - Toxic products in cabin air

- Analysis of service events shows that engines are not the major contributor to accidents

What is in Oil?

Synthetic Jet engine oils – Exposed to very high temps (>700^{0}F / 371^{0}C)

- Base stock (95%) – Polyol esters – pyrolysis
- Organophosphate (TCP, Tricresyl phosphate): Antiwear additive: 3%~
  - Neurotoxin; Toxicity known since 1930s
  - Irritant (skin, eyes, respiratory tract, mucous membranes)
  - (Ortho isomers in oil <0.01% [<0.1%*] - Should not be seen as 'non hazardous'
- PAN – n-phenyly-alpha-napthylamine: Antioxidant: 1%
  - 'IRRITANT -Hazardous substance – Sensitization properties
    R 43 – sensitization by skin contact – long-term/repeat
  - ST effects (skin, eye, mucous membrane irritant; effects on blood
  - Contaminant: BNA, CAT 1, Sched 1 carcinogen & PBN (cat 3)
- WIDE RANGE OF PYROLYSIS PRODUCTS

What is the Problem?

- No contaminated air sensors fitted
- Bleed air is not filtered
- Oil is hazardous/toxic
- Triaryl phosphates – Durad 125 (aviation lubricants formulation of TCP) & non ortho TCP isomers (TPCP) almost as inhibitory as TOCP (Baker/Cole/Furlong 2012)

There are very real health & flight safety implications

Oil Warnings

1998-2004

‘Warning! Contains Tricresyl Phosphate

- **Prolonged or repeated breathing of oil mist or prolonged or repeated skin contact can cause nervous system effects.**
- **Avoid prolonged or repeated overexposure to skin or lungs.’**

2004:

‘This product is not expected to produce adverse health effects under normal conditions of use and with appropriate personal hygiene practices. Product may decompose at elevated temperatures or under fire conditions and give off irritating and/or harmful (carbon monoxide) gases/vapors/fumes. Symptoms from acute exposure to these decomposition products in confined spaces may include headache, nausea, eye, nose, and throat irritation.’

Leaking oil is an abnormal condition of use – Mobil 2000; Risk assessments- not done X

Warnings – selected examples only

1990: Mobil: "It is reasonable to assume that a hazard exists by inhalation of mists or vapors of aryl phosphate esters."

1969: Rolls-Royce: Oil evaporation loss is minor part of oil consumption only, with major part being loss of oil from permissible leakage past certain seals, escape of mist / aerosol via breathers, loses during inspections/servicing.

1999: Australian regulator, CASA: Oil fumes leaking into the air supply is a 'feature of the basic design of air-conditioning systems in aircraft being bleed air from engines'

Warnings – selected examples only

1999: UK Government – "Inhalation of mists containing TCP… would be hazardous & TCP is toxic"

2003: Rolls-Royce, Germany – "Any oil leaking from an engine, entering the aircraft customer bleed offtake is classified as HAZARDOUS"

2003:German Regulator, LBA: Oil leakage… and oil residues… may lead to harmful contamination of the cabin air and cause intoxication of the flight crew

1953 - B 52

- Boeing- B 52 Decontamination program – smoke / odor repeatedly reported/permeates nasal passages, clothing, cabin lining… lingers for substantial time…
- Possible toxic effect still unknown

1954 – Douglas- Engine Bleed Air Contamination Study

15 January 1954 Report No. SM 15195

ENGINE COMPRESSOR BLEED AIR CONTAMINATION STUDY

XC-132 PROJECT

DOUGLAS

Prepared by: R. W. Maddock

Approved by: J. L. Allen
J. L. Allen

Approved by: W. W. Reaser
W. W. Reaser, Chief
Air Conditioning Engineer

COPY NO. 5

Contract Number
AF33(600)-23055

DOUGLAS AIRCRAFT COMPANY, INC.
Santa Monica, California

- Bleed air temps to be kept below oil ‘cracking & thermal decomposition’ temps;
- Felt much more could be done to reduce this contamination at its source

1954 – The Toxicity of Certain Lubricants, Engine Oils…..Thermal Decomposition- TREON- USAF study

WADC TECHNICAL REPORT 54-344

THE TOXICITY OF CERTAIN LUBRICANTS, ENGINE OILS, AND CERTAIN OF THEIR CONSTITUENTS, WITH PARTICULAR REFERENCE TO THE PRODUCTS OF THEIR THERMAL DECOMPOSITION

JOSEPH F. TREON
FRANK P. CLEVELAND
JOHN CAPPEL

KETTERING LABORATORY
UNIVERSITY OF CINCINNATI

NOVEMBER 1954

AERO MEDICAL LABORATORY
CONTRACT No. AF 33(038)-26456
RDO No. 698-31

WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

Carpenter Litho & Prtg. Co., Springfield, O.
200 - 21 April 1955

- Inhalation study
- Toxicity arises from breakdown of base stock (95% of oil) – Thermal decomposition products
- Mists at 600^{o}F (315 ^{o}C) very much more toxic than those formed at 450-500^{o}F.
- Pneumonitis, degenerative changes to liver, brain & kidneys

My Dissertation - Research Questions

- What health effects are being reported in crew exposed to contaminated bleed air?
- What monitoring has been undertaken, can such data be used to assess exposure impact on human health?
- How often do contaminated bleed air events occur and what are the flight safety implications?
- Have the aviation industry and Governments dealt with the contaminated bleed air issue appropriately?

2010 - Germany, Flight Safety

- December 2010 (A319) - BFU report (released in October 2012)
- Capt: strong dizziness, loosing senses, sudden tunnel vision, tingling hands & feet, stretched to the limit of capacities;
- Co-pilot : Feeling of throwing up, couldn't handle the flight info and general flight status

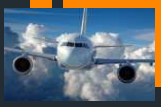
(FO: felt very bad, loose feeling in hands and feet…"Oh my god, please make us land safely, please let us survive, Goddammit, what can I do?")

- **1 pilot incapacitation / 1 pilot partial incapacitation**
- **Co-Pilot off work sick for 6 months...**

My Story

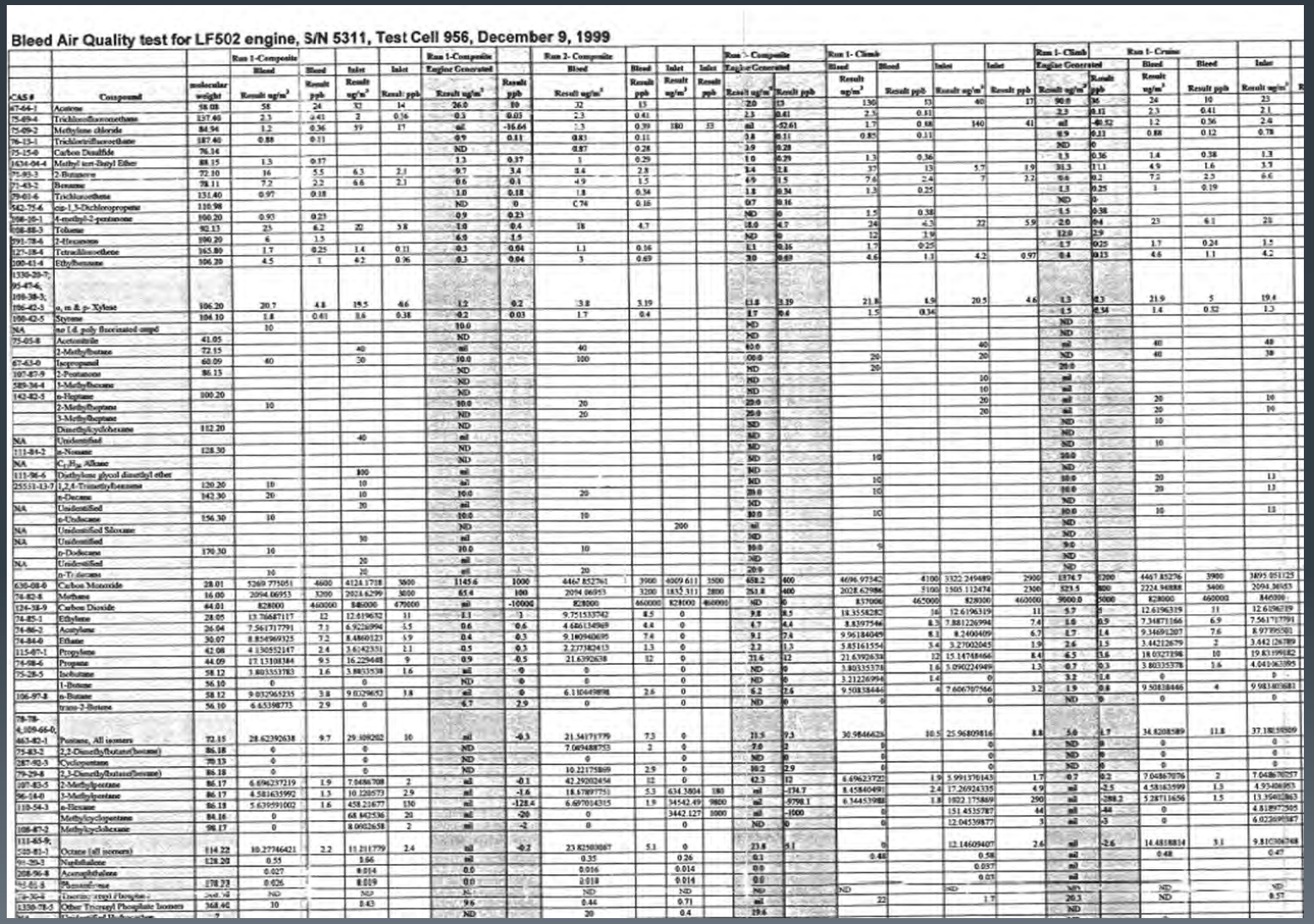
- BAe 146 1994-1997
- Repeat dirty sock odour at transient flight operations (oil)
- Acute adverse effects
- Loss of CASA medical certification in 1997 after escalation of Symptoms
- Selected long-term effects remain 15 years on

Safety/Health – 1999 - Malmö



- Both pilots temporarily totally incapacitated in flight.
- Oil leak identified.
- Oil-based chemicals identified in air supply system; (including TCP) no other explanation for symptoms.
- Captain no longer able to fly – loss of medical cert

Chemicals Identified in the Air Supply on that Swedish Flight



Bleed Air Quality test for LF502 engine, S/N 5311, Test Cell 956, December 9, 1999

CAS #	Compound	molecular weight	Run 1-Composite Bleed Result ug/m³	Bleed Result ppb	Inlet Result ug/m³	Inlet Result ppb	Run 1-Composite Engine Generated Result ug/m³	Result ppb	Run 2- Composite Bleed Result ug/m³	Bleed Result ppb	Inlet Result ug/m³	Inlet Result ppb	Run 3- Composite Engine Generated Result ug/m³	Result ppb	Run 1- Climb Bleed Result ug/m³	Bleed Result ppb	Inlet Result ug/m³	Inlet Result ppb	Run 1- Climb Engine Generated Result ug/m³	Result ppb	Run 1- Cruise Bleed Result ug/m³	Bleed Result ppb	Inlet Result ug/m³
67-64-1	Acetone	58.08	58	24	32	14	26.0	10	32	13			2.0	13	130	53		17	90.0	36	24	10	23
75-69-4	Trichlorofluoromethane	137.40	2.3	0.41	2	0.36	0.3	0.05	2.3	0.41			2.3	0.41	2.3	0.41			2.3	0.41	2.3	0.41	2.1
75-09-2	Methylene chloride	84.94	1.2	0.36	59	17	nd	-16.64	1.3	0.39	180	53	nd	-52.61	1.7	0.48	140	41	nd	-40.52	1.2	0.36	2.4
76-13-1	Trichlorotrifluoroethane	187.40	0.88	0.11			0.9	0.11	0.83	0.11			3.8	0.51	0.85	0.11			0.9	0.12	0.88	0.12	0.78
75-15-0	Carbon Disulfide	76.14					ND		0.87	0.28			2.9	0.28					ND	0			
1634-04-4	Methyl tert-Butyl Ether	88.15	1.3	0.37			1.3	0.37	1	0.29			1.0	0.29	1.3	0.36			1.3	0.36	1.4	0.38	1.3
75-83-3	2-Butanone	72.10	16	5.5	6.3	2.1	9.7	3.4	8.4	2.8			4.9	1.6	37	13	5.7	1.9	31.3	11.1	4.9	1.6	3.9
71-43-2	Benzene	78.11	7.2	2.2	6.6	2.1	0.6	0.1	4.9	1.5			4.9	1.5	7.6	2.4	7	2.2	0.6	0.2	7.2	2.3	6.6
79-01-6	Trichloroethene	131.40	0.97	0.18			1.0	0.18	1.8	0.34			1.8	0.34	1.3	0.25			1.3	0.25	1	0.19	
542-75-6	cis-1,3-Dichloropropene	110.98					ND	0	C 74	0.16			0.7	0.16					ND	0			
108-10-1	4-methyl-2-pentanone	100.20	0.93	0.23			0.9	0.23					ND	0	1.5	0.38			1.5	0.38			
108-88-3	Toluene	92.13	23	6.2	22	5.8	1.0	0.4	18	4.7			18.0	4.7	24	6.3	22	5.9	2.0	0.4	23	6.1	21
591-78-6	2-Hexanone	100.20	6	1.5			6.9	1.5					ND	0	12	2.9			12.0	2.9			
127-18-4	Tetrachloroethene	165.80	1.7	0.25	1.4	0.21	0.3	0.04	1.1	0.16			1.1	0.16	1.7	0.25			1.7	0.25	1.7	0.24	1.5
100-41-4	Ethylbenzene	106.20	4.5	1	4.2	0.96	0.3	0.04	3	0.69			3.0	0.69	4.6	1.1	4.2	0.97	0.4	0.13	4.6	1.1	4.2
1330-20-7; 95-47-6; 108-38-3; 106-42-3	o, m & p- Xylene	106.20	20.7	4.8	19.5	4.6	1.2	0.2	3.8	3.19			11.8	3.19	21.8	4.9	20.5	4.6	1.3	0.3	21.9	5	19.4
100-42-5	Styrene	104.10	1.8	0.41	8.6	0.38	0.2	0.03	1.7	0.4			1.7	0.4	1.5	0.34			1.5	0.34	1.4	0.32	1.3
NA	no 1-4 poly fluorinated cmpd		10				10.0						ND						ND				
75-05-8	Acetonitrile	41.05					ND						ND						ND				
	2-Methylbutane	72.15			40		nd		40				40.0				40		nd		40		40
67-63-0	Isopropanol	60.09	40		30		10.0		100				00.0		20		20		ND		40		30
107-87-9	2-Pentanone	86.13					ND						ND		20				20.0				
589-34-4	3-Methylhexane						ND						ND				10		nd				
142-82-5	n-Heptane	100.20					ND						ND				10		nd				
	2-Methylheptane		10				10.0		20				20.0				20		nd		20		10
	3-Methylheptane						ND		20				20.0				20		nd		20		10
	Dimethylcyclohexane	112.20					ND						ND						ND		10		
NA	Unidentified				40		nd						ND						ND				
111-84-2	n-Nonane	128.30					ND						ND						ND		10		
NA	C_nH_{2n} Alkane						ND						ND		10				10.0				
111-96-6	Diethylene glycol dimethyl ether				100		nd						ND						ND				
25551-13-7	1,2,4-Trimethylbenzene	120.20	10		10		nd						ND		10				10.0		20		13
	n-Decane	142.30	20		10		10.0		20				20.0		10				20.0		20		13
NA	Unidentified				20		nd						ND						ND				
	n-Cyclocane	156.30	10				10.0		10				30.0		10				10.0		10		12
NA	Unidentified Siloxane						ND				200		nd						ND				
NA	Unidentified				30		nd						ND						ND				
	n-Dodecane	170.30	10				10.0		10				10.0						9.0				
NA	Unidentified				20		nd						ND						ND				
	n-Tridecane		10		20		nd		20				20.0						ND				
630-08-0	Carbon Monoxide	28.01	5269 775051	4600	4124.1718	3600	1145.6	1000	4467.852761	3900	4009.611	3500	458.2	400	4696.97342	4100	3322.249489	2900	1374.7	1200	4467.85276	3900	3895.951125
74-82-8	Methane	16.00	2094.06953	3200	2024.6299	3000	65.4	100	2094.06953	3200	1835.311	2800	263.8	400	2028.42986	3100	1505.112474	2300	323.5	500	2224.94888	3400	2094.36953
124-38-9	Carbon Dioxide	44.01	828000	460000	846000	479000	nd	-10000	828000	460000	828000	460000	ND	0	837000	465000	828000	460000	9000.0	5000	828000	460000	846000
74-85-1	Ethylene	28.05	13.76687117	12	12.6196732	11	1.1	1	9.751533742	8.5	0		9.8	8.5	18.3558282	16	12.6196319	11	6.7	6	12.6196319	11	12.6196319
74-86-2	Acetylene	26.04	7.561737791	7.1	6.9228994	6.5	0.6	0.6	4.686134969	4.4	0		4.7	4.4	8.8397546	8.3	7.881226994	7.4	1.9	1.8	8.9739501	7.6	7.561737791
74-84-0	Ethane	30.07	8.854969325	7.2	8.4860123	6.9	0.4	0.3	9.190340695	7.4	0		9.1	7.4	9.961840491	8.1	8.2400409	6.7	8.7	7.1	9.34691207	7.6	8.9739501
115-07-1	Propylene	42.08	4.130552147	2.4	3.6142331	2.1	0.5	0.3	2.277382413	1.3	0		2.2	1.3	5.85161554	3.4	3.27002045	1.9	2.6	1.5	3.44212679	2	3.442126789
74-98-6	Propane	44.09	17.13108384	9.5	16.229448	9	0.9	0.5	21.6392638	12	0		21.6	12	21.6392638	12	15.14748466	8.4	6.5	3.6	18.0327198	10	19.83199482
75-28-5	Isobutane	58.12	3.803533783	1.6	3.8033538	1.6	nd	0	0		0		ND	0	3.803353783	1.6	5.0902249489	1.3	0.7	0.3	3.80335378	1.6	4.049463895
	1-Butene	56.10	0		0		ND	0	0		0		ND	0	3.211226994	1.4	0		3.2	1.4	0		0
106-97-8	n-Butane	58.12	9.0329655235	3.8	9.0329652	3.8	nd	0	6.110449898	2.6	0		6.2	2.6	9.50838444	4	7.6067077566	3.2	1.9	0.8	9.50838446	4	9.583403681
	trans-2-Butene	56.10	6.65398773	2.9	0		6.7	2.9	0		0		ND	0			0		ND	0	0		0
78-78-4, 109-66-0, 463-82-1	Pentane, All isomers	72.15	28.62392638	9.7	29.1092202	10	nd	-0.3	21.54171779	7.3	0		21.5	7.3	30.9846626	10.5	25.96809816	8.8	5.6	1.7	34.8208589	11.8	37.18159509
75-83-2	2,2-Dimethylbutane(hexane)	86.18	0		0		ND		7.069488753	2	0		7.0	2	0		0		ND	0	0		0
287-92-3	Cyclopentane	70.13	0		0		ND		0		0		ND	0	0		0		ND	0	0		0
79-29-8	2,3-Dimethylbutane(hexane)	86.18	0		0		ND		10.22175869	2.9	0		10.2	2.9	0		0		ND	0	0		0
107-83-5	2-Methylpentane	86.17	6.696257219	1.9	7.0486708	2	nd	-0.1	42.29202454	12	0		42.3	12	6.696233722	1.9	5.991370143	1.7	0.7	0.2	7.04867076	2	7.048670257
96-14-0	3-Methylpentane	86.17	4.581633992	1.3	10.320573	2.9	nd	-1.6	18.67897751	5.3	634.3804	180	nd	-174.7	8.45840491	2.4	17.26924335	4.9	nd	-2.5	4.58163599	1.3	4.934486953
110-54-3	n-Hexane	86.18	5.639591002	1.6	458.21677	130	nd	-128.6	6.697014315	1.9	34542.49	9800	nd	-9798.1	6.344539882	1.8	1022.175869	290	nd	-288.2	5.28711656	1.5	13.39402863
	Methylcyclopentane	84.16	0		68.842536	20	nd	-20	0		3442.127	1000	nd	-1000	0		151.4535787	44	nd	-44	0		4.818977305
108-87-2	Methylcyclohexane	98.17	0		8.0902658	2	nd	-2	0		0		ND	0	0		12.04539877	3	nd	-3	0		6.022698987
111-65-9; 540-84-1	Octane (all isomers)	114.22	10.27746421	2.2	11.211779	2.4	nd	-0.2	23.82503067	5.1	0		23.8	5.1	0		12.14609407	2.6	nd	-2.6	14.4818814	3.1	9.810306748
91-20-3	Naphthalene	128.20	0.55		1.66		0.1		0.35		0.26		0.3		0.48		0.58		nd		0.48		0.47
208-96-8	Acenaphthalene		0.027		0.054		0.0		0.016		0.014		0.0				0.057		nd				
85-01-8	Phenanthrene	178.23	0.026		0.019		0.0		0.018		0.014		0.0				0.03		nd				
84-74-2	Dibutyl phthalate	278.34	ND		ND		ND		ND		ND		ND		ND		ND		ND		ND		ND
1330-78-5	Other Trimethyl Phosphate Isomers	368.40	10		8.43		9.6		0.44		0.71		nd		22		1.7		20.3		ND		8.57
							ND		20		0.4		19.6						ND				

An Actual Incident

Recent Repeat Events at US Airways – (Murawski, AIAA 2011)

- 11 documented events Dec 28, 2009 -Mar 16, 2010; B767
- Majority were documented oil and/or hydraulic fluid contamination; others were likely residual oil/HF contamination, breathing air supplied through dirty ventilation ducts
- At least six pilots, 25 FA still ill; tremors, memory problems, fatigue, poor balance, chronic headaches, etc; one FA and one pax had strokes
- 2 pilots off same flight lost medicals

Germany - 2011

- November 2011 (B737): Shortly after rotation a pungent smell developed… the health condition of the… pilot flying deteriorated, about 5 minutes into the flights the first officer suffered from a sudden and strong nausea… pale with his eyes being red with increased flow of lacrimal fluid. The heart beat rate dropped from about 100 to about 80… a blood sample was taken. Positive for TOCP/Bche - German BFU
- "Exposure to tri-o-cresyl phosphate detected in jet airplane passengers." Liyasova et al. Toxicol Appl Pharmacol. 2011 Jun 24
- Captain off work, long-term sick


ARTICLE IN PRESS

Toxicology and Applied Pharmacology

Exposure to tri-o-cresyl phosphate detected in jet airplane passengers

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UK- 2000 - AAIB

- *'Oily metallic smell on the flight deck also evident previous sector. On this occasion, numerous ATC calls were missed, prompting ATC to ask a/c "if everything was all right". P1 then forgot to slow a/c during approach until reminded to do so by ATC at 3.7d (miles). Crew unaware that they were becoming partially incapacitated..'*
- *Emergency oxygen used for go-around and next landing*
- *Crew considered oil source after landing, No defects found.*
- *Further oil fumes reported 4 days later with oil leakage traced to APU*

Safety/Health

- Cara: Medically retired at 29, BAe 146
- undiagnosed neurological symptoms(dizziness, cognitive partial grey outs…)
- Aerotoxic pattern
- High rate of ill health reported in airline

Offshore Industry, Norway Harry

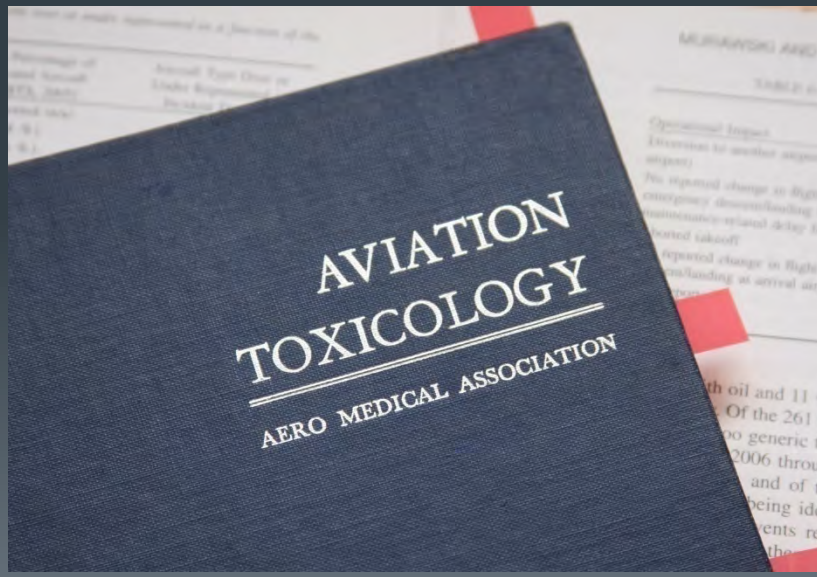
- Dattera mi har aldri sett en far uten helseproblemer

Slående likheter mellom skadde piloter og

In case you've forgotten !!!

- Pyrolyzed oil "can contain irritant and toxic aldehydeand other dangerously toxic products of incomplete combustion…" (Stovell, 1953)

"Even a small degree of bodily impairment from toxic gases would lead to increased pilot error and so be hazardous in aviation."



Awareness

Extensive awareness in 1950s and 1960s

- Exposure to synthetic lubricants: Hazardous / Toxic- TREON (USAF) 1954……
- Critical temp: (> 600^{0}F /316^{0C}): Degradation of base stock/TCP
- Contamination of air was key concern: Design/performance
- Concern of rising engine temperatures & toxicity – forgotten by 1970
- Adverse effects in crews

General

- Industry awareness – Extensive: To the – present day
- Engines temps routinely used above critical oil temps
- Engine compressor bleed air fails to meet certification and safety analysis requirements as occurrence > 10^{-5}(remote)
- Wide variety of regulations (oil leakage) fail to be met

Frequency of Contaminated Air Events

- Records incomplete/ under-reporting is very common;
- Events are NOT rare
- 32% of contaminated air events involved crew impairment;
- Oxygen rarely used
- Significant flight safety events identified;
- Airline: Oil fumes reported in 1% of flights at major UK airline
- Engineering is often not finding source of fumes with aircraft dispatched with repeat events
- Design & operation of oil seal system explains frequency

Frequency of Events

- Significant under-reporting and contaminated air events not rare;
- Regulator/airline/manufacturer databases are unreliable;
- Less than 4% of events are reported;
- It is not possible to determine a reliable rate of contaminated air events – (EASA 2009);
- **Seal design fails to prevent oil leakage over the full engine operating range and seal wear provide the basis for oil leakage at lower levels. This is an inadequate design and operational feature of using bleed air;**
- Industry focus has incorrectly been placed on maintenance failures;
- Lower level synthetic oil leakage is an **expected / accepted** occurrence of the bleed air system.

Air Quality Monitoring

General air studies	'n'	Contaminated air studies	'n'
General air studies - no fume events (38%)	20	Contaminated air studies - (62%)	35
Epidemiological studies – during monitoring (no fume event)	06	Fume event *short duration/minor	01
Epidemiological studies – Not during monitoring (no fume event)	2	Epidemiological studies – not during monitoring (no fume event)	05
Cabin air deemed acceptable (60%)	12	**TCP found (51%)**	18
		Oil constituents identified as source (66%)	23
		Cabin air deemed acceptable (32%)	11

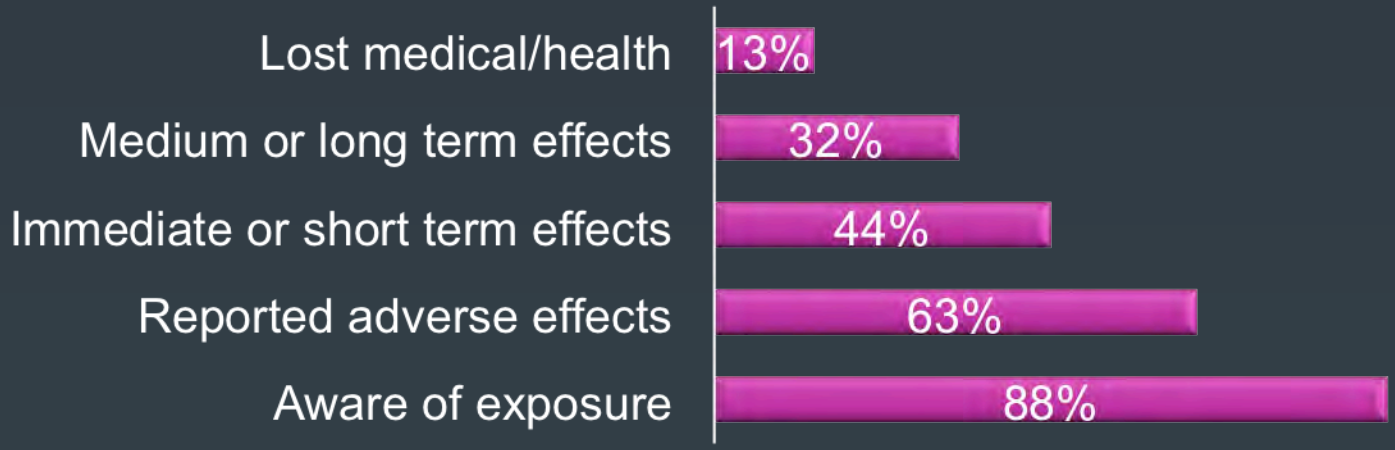
- Epidemiological studies of very limited benefit
- Air deemed acceptable: strong industry affiliation

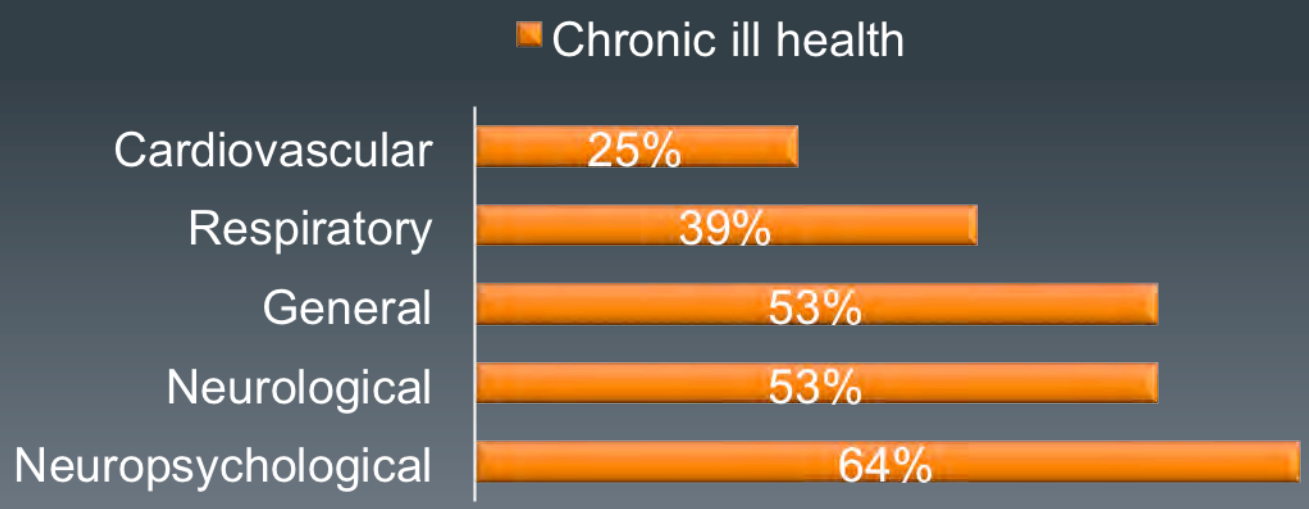
Air Quality Monitoring

- Oil studies – Extensive;
- 1954: USAF – Toxicity of heated synthetic oils identified;
- Study techniques – generally inadequate;
- Analysis of results – inappropriate;
- General air quality monitoring studies (36% of studies) have been inappropriately widely used to suggest acceptability (60%) of cabin air;
- Specific contaminated air studies were of mixed value; with oil identified in 66% and TCP identified in 51% of the studies;
- Epidemiological studies are of very limited value and can't be used to suggest air is safe & not able to cause adverse effects
- **UK Government studies: TCP found in 23% of flights – "Normal flights" with oily… fumes reported in 38% of the flights – UK Cranfield study… considered safe (Swab sampling IOM findings were similar) 2011/12**

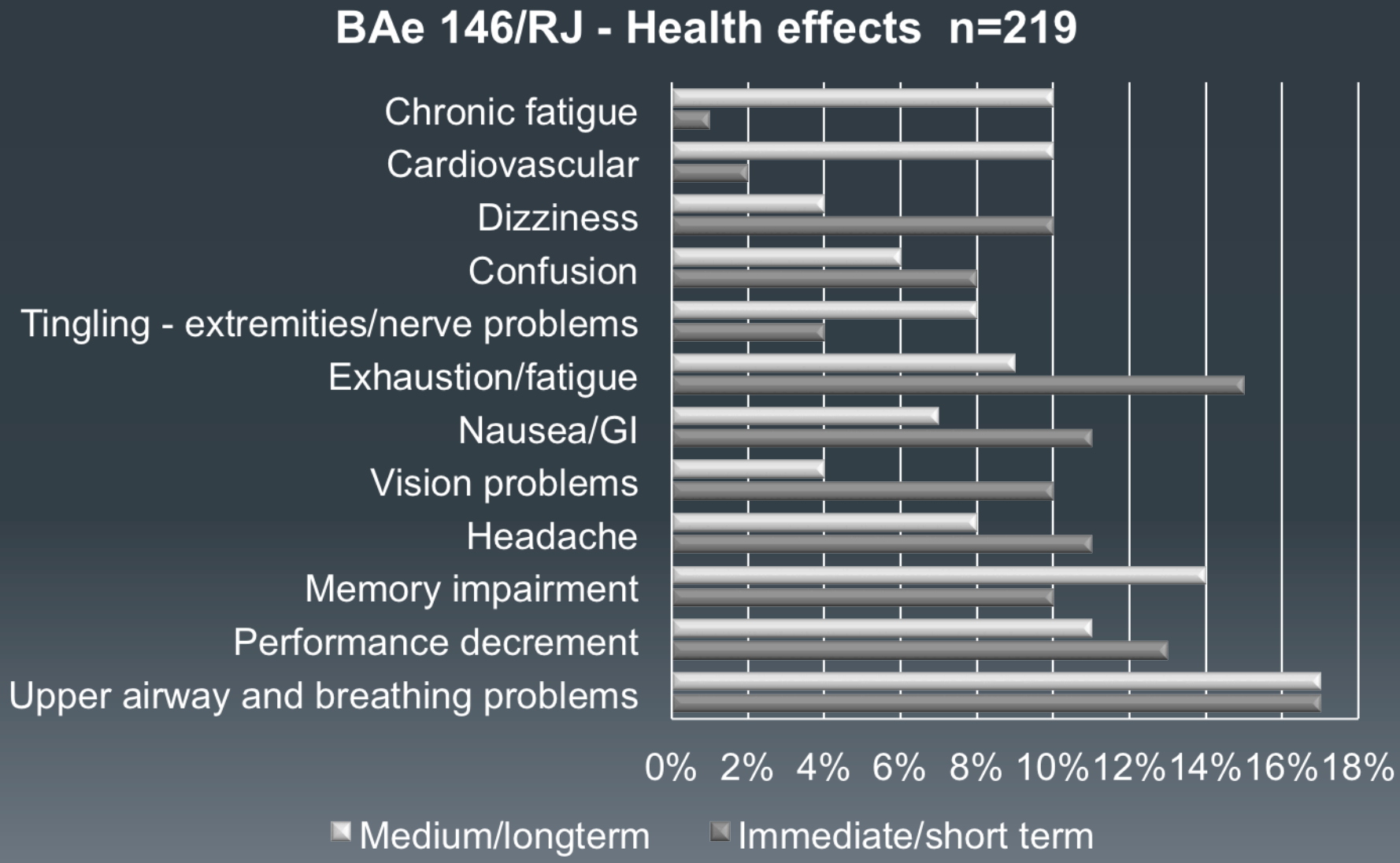
Health Effects

BAe 146/RJ Adverse health effects. n=274





Health Effects



Aerotoxic Syndrome (2000)

Studies show consistent pattern of acute and chronic symptoms/ dysfunction

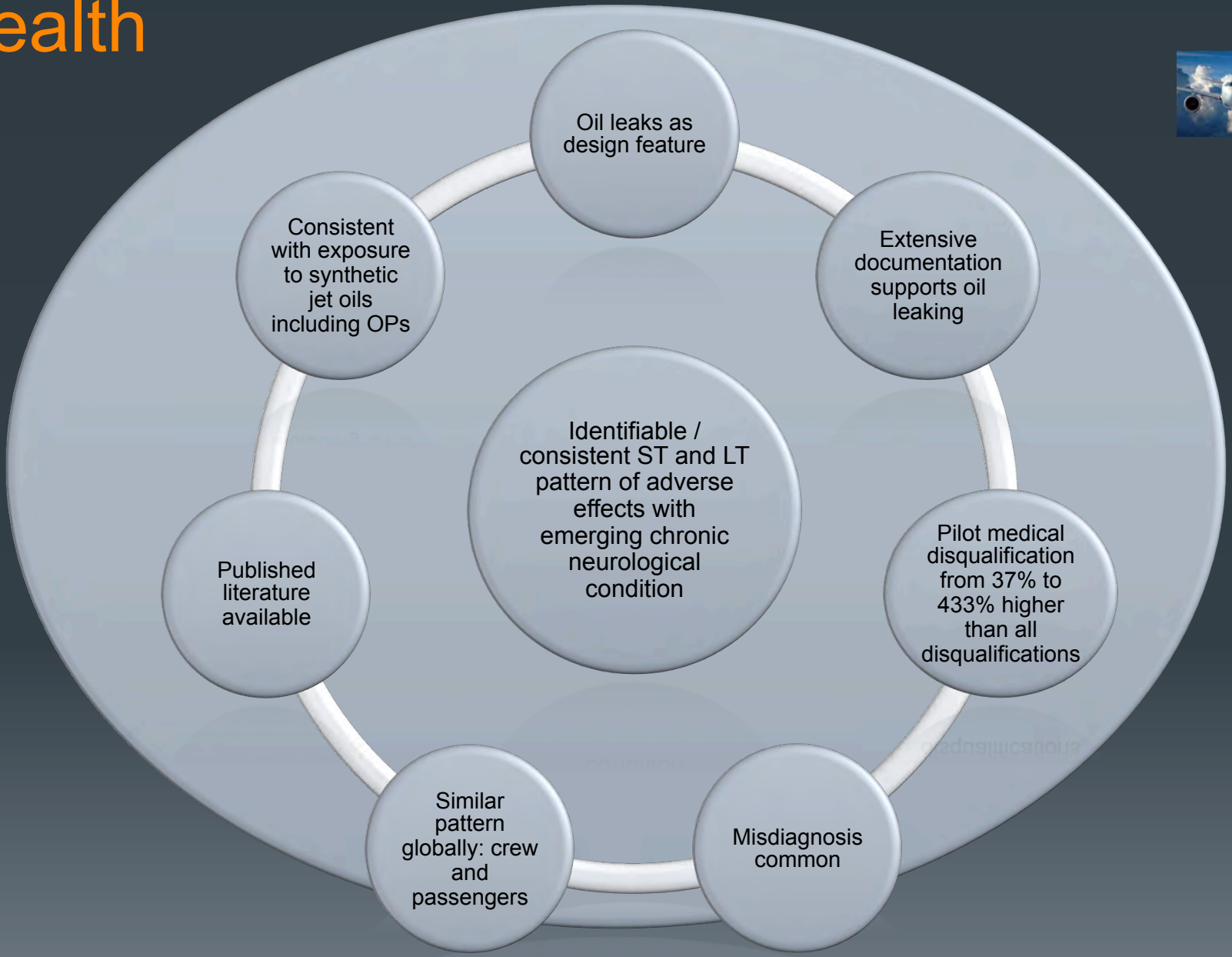
Causative relationship exists

Illness from a complex set of symptoms resulting from unique occupational environment

Specific symptoms can vary between people but general types of symptoms remarkably consistent.

Term Aerotoxic Syndrome is valid

Health


Oil leaks as design feature
Extensive documentation supports oil leaking
Pilot medical disqualification from 37% to 433% higher than all disqualifications
Misdiagnosis common
Similar pattern globally: crew and passengers
Published literature available
Consistent with exposure to synthetic jet oils including OPs
Identifiable / consistent ST and LT pattern of adverse effects with emerging chronic neurological condition

My PhD - Conclusions

- Adverse effects with temporal association are evident;
- Monitoring cannot be used to say cabin air is satisfactory;
- Contaminated air is a function of design and operation of bleed air systems and therefore explains frequency;
- Awareness of issue dates back to 1950s;
- The problem remains unresolved and flight safety continues to be compromised;
- Lubricant manufacturer raises toxicity concerns with EASA;
- Solutions exist: Bleed free technology is now flying on the Boeing 787 and filtration solutions exist.

The data from this presentation was extracted from the PhD Thesis by Susan Michaelis (2011) entitled: "Health and Flight Safety Implications from Exposure to Contaminated Air in Aircraft".

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www.susanmichaelis.com

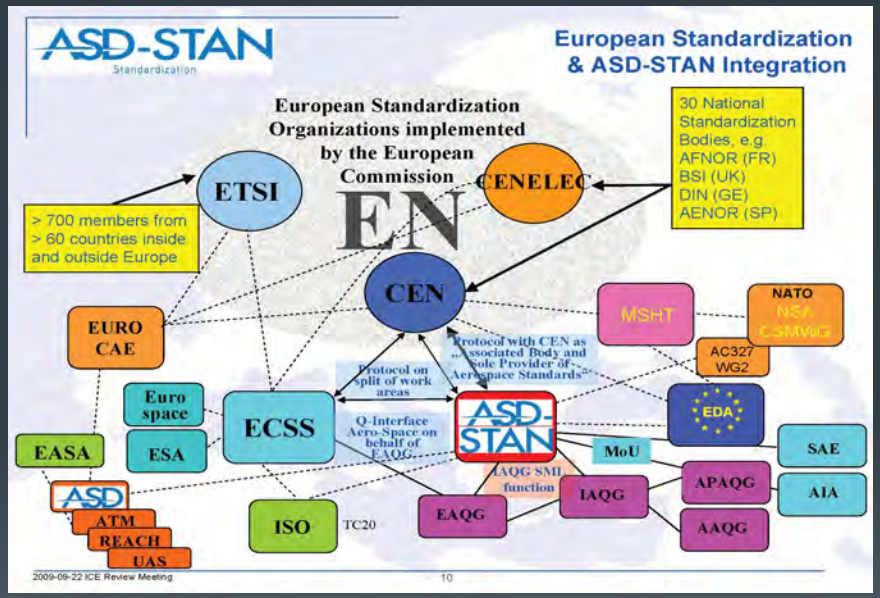
Other Factors to Consider

- Low level effect of mixtures; synergistic effects, reduced pressure environment, humidity
- ACGIH TLVs not suitable for aircraft environment
- Genetic and environmental individual variability
- OH&S regulations are not being met in most countries:
  - UK: HSE/CAA Memorandum of understanding – CAA takes lead & neither enforcing HSE regulations
  - USA: FAA takes Federal priority over OSHA & does not enforce regulations
  - EU: OSHA regulations: Not being met due to EASA/aviation lead
- REACH: Not being met
- EU (ASD-STAN) attempt to set health, safety & comfort standards (no toxicology included); SAe doing similar

What is Happening?

- UK House of Lords – 2000 – airlines should monitor air to *'refute' common allegations of poor cabin air quality*….
- 56 million euros in EU cabin air studies – fail to address contaminated air
- Extensive range of industry/Government studies used to delay action/ provide uncertainty / no safety case
- "Reprehensible conduct" has been shown throughout industry with some minor actions now starting to occur by a select few
  - filtration trials; research on detection systems; Germany; NYCO oils etc…
- Documentation available is overwhelming to objective observer
- Boeing 787 is the answer as no longer uses bleed air for the cabin

EU Cabin Air Standards



EU standardisation project (ASD-STAN)

- Represent EU industry to promote it's interests….
- Halted with 2 public enquiries to be held
- EU/Industry cabin air studies- 56 million euros
- No toxicology/ ground based standards should not apply- (SAE, 2012)

TCP -Why are these Isomers of Interest?

A Very Brief History of TCP Exposures

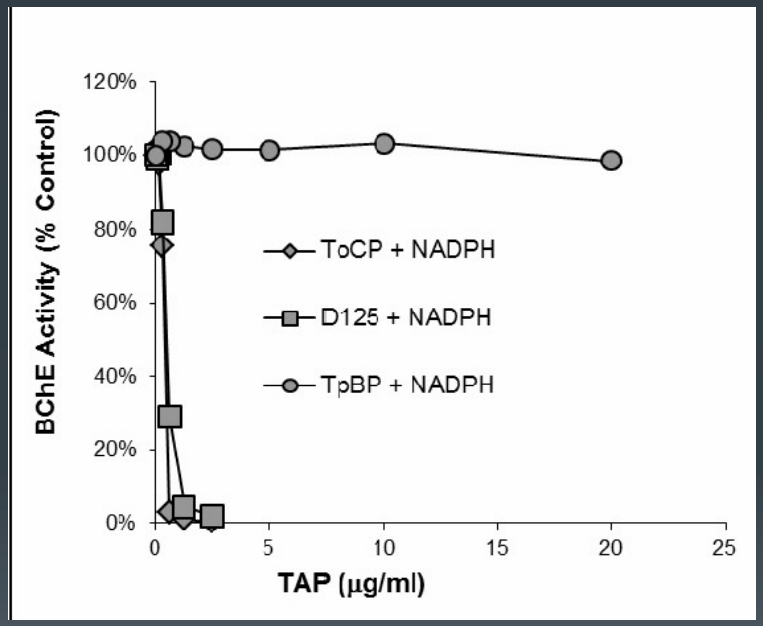
- **1930**
  -TOCP identified as the cause of paralysis in Ginger Jake Syndrome (Smith et al.)
- **1954**
  -TOCP has to be converted to toxic metabolite (~ in the liver -Aldridge)

- **1958**

Henschler – MOCP & DOCP more toxic than TOCP

- **1961**
  - Structure of toxic metabolite (cyclic saligenin phosphate) determined by John Casida

TCP - 2012



- D 125 bioactivates into enzyme inhibitors slightly less well than TOCP that paralyzed 50,000 people during prohibition
- TPCP and other Triaryl isomers found to adversely effect normal physiological processes

Baker et al (2012): safer anti-wear triaryl phospahte additives for jet engine lubricants.

Will they listen?

http://www.headinthesandsymposium.com/event-news.html


HOUSTON WE HAVE A PROBLEM
James Lovell, Apollo 13

Thank you

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