Belfort Group citizens in action

CASE ORANGE

CONTRAIL SCIENCE, ITS IMPACT ON CLIMATE AND WEATHER MANIPULATION PROGRAMS CONDUCTED BY THE UNITED STATES AND ITS ALLIES

Compiled for the Belfort Group,

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If we can stand up to them, all Europe may be free and the life of the world may move forward into broad, sunlit uplands. But if we fail, then the whole world, including the United States, including all that we have known and cared for, will sink into the abyss of a new Dark Age made more sinister, and perhaps more protracted, by the lights of perverted science.

Winston Churchill, 'This was their finest hour' speech to the House of Commons, June 18th 1940.

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LIST OF ABBREVIATIONS:

AFB	Air Force Base
ATP	Airline Transportation Pilot
ATSDR	Agency for Toxic Substances and Disease Registry
AWACS	Airborne Early Warning and Control System
BKN	Broken clouds
°C	Degrees Celsius
Ci	Cirrus
Cc	Cirrocumulus
CO	Carbon Monoxide
DLR	Deutsches Institut fur Raumfahrt
DOD	Department of Defense
DTR	Diurnal Temperature Range
ECM	Electronic Counter Measures
ELF	Extreme Low Frequency
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FIR	Flight Information Region
ft	Feet
GWP	Global Warming Potential
HAARP	High Frequency Active Auroral Research Program
HC	Hydrocarbons
HMSO	Her Majesty's Stationary Office
Hz	Herz
ICAO	International Civil Aviation Organization
IPCC	International panel for Climate Change
Kg	Kilogram
KW	Kilowatt
Lbs	Pounds
NASA	National Air and Space Agency
NATO	North Atlantic Treaty Organization
SALT	Strategic Arms Limitations Talks
Sct	Scattered clouds
SN	Smoke Number
SOP	Standard Operating Procedure
UEA	University of East Anglia
UIR	Upper Information Region

USSR	Union of the Socialist Soviet Republics
VLF	Very Low Frequency
WMO	World Meteorological Order

1. EXECUTIVE SUMMARY

1. EXECUTIVE SUMMARY:

This unclassified research paper has been compiled on request of the Belfort Group, a Belgian environmental watchdog. It highlights the specific problems associated with contrails emitted by aircraft, the manipulation for geo-engineering or defense purposes of some of these trails by the United States government and the subsequent effect on quality of life. In order to force public debate on the subject this document has not only been transmitted to embassies of states that organize weather manipulations projects, news agencies and interest groups in this field but also to organizations in countries that are not considered as allied forces by the United States and NATO.

Contrails are not the harmless emissions of aircraft at high altitude that only have an esthetic impact on the sky as meteorologists suggest. They do not only contain huge amounts of water vapor, but also significant amounts of Carbon Dioxide, Nitric Oxide, Sulfur Oxide and soot that have a significant impact on public health. In that respect it is noteworthy that derogations for emissions of Hydrocarbons and Carbon Monoxide have been granted for engines of some military aircraft, which exceed civil regulatory levels in a very significant way. Chapter 3 contains a detailed description how contrails are formed, its detailed chemical composition plus a very interesting case study of the KC135 tanker & E-3 Sentry (AWACS) aircraft, the latter being operated on a Luxemburg registration without complying to civil standards.

Persistent contrails have a devastating impact on eco-systems on Earth. They develop in men made Cirrus cloud that can cover a significant part of the sky. It is scientific evidence that those aviation-induced clouds already occupy 3 to 5% of the sky in Europe and this figure increases by 1 to 2% per decade. As these types of clouds are not classified as such by the WMO, the World Meteorological Organization, there is obviously no tendency to research this subject thoroughly and subsequently civil aviation authorities and other government bodies write the thesis of 'chemtrails' off as a hoax. Nevertheless it is proven that the existence of these persistent contrails has a negative impact on temperature and they can alter precipitations levels. It also induces the dehydration of the stratosphere. Chapter 4 provides a summary of the most striking results of scientific research on this subject.

Given the extensive history record of weather manipulation projects, conducted mainly by the United States armed forces, the relationship between men made contrails and its impact on different climatologic parameters creates a scientific basis for a weather manipulation system. Chapter 5 contains a detailed overview of the major weather modification operations in human history, starting from relatively innocent endeavors such as cloud seeding with silver iodide over ionospheric heating to large-scale geo-engineering projects through commercial aviation. Patents, previously classified documents, order forms for Barium and maps with daily spraying schemes irrevocable denote the existence of a global military sponsored and governmental approved project for alteration of the upper troposphere for global control purposes. The technical details, including the nature of the seeding material and its possible impact on public health, are also included in chapter 5.

Finally the investigation group, which wants to remain anonymous until further notice, comes to the final conclusion that atmospheric seeding for the sake of military interests and a global business model has a devastating impact on eco-systems on this planet and quality of life in general. This practice is therefore considered as unacceptable.

10/05/10

PV

2. NOMENCLATURA

Give me a long enough lever and a place to stand on and I will move the earth.

Archimedes (287 – 212 B.C.)

2. NOMENCLATURA:

A distinction is made between contrails, distrails, wingtip vortices and 'chemtrails'. In this research paper only contrails and chemtrails are subject to an in-depth study.

2.1. CONTRAILS:

Contrail is the contraction of the words 'condensation' and 'trail', the condensation of engine exhausts. The word dates back to World War II and contrails were considered as a nuisance as they attracted enemy fighters in the fray.

B-17 heavy bombers are on their way to Schweinfurt, emitting substantial amounts of contrails. German pilots could easily pick out the exact position of individual planes by their contrails.[1]

In contrary to popular belief contrails are not exclusively formed by jet aircraft, but also by propeller driven airplanes, providing that their operating altitude is suitable for their formation. This phenomenon is temperature related. As temperature drops with 2°C/1000 ft altitude gain in a standard atmosphere and a cold air parcel can only hold very limited water vapor any hot exhaust fumes automatically condense into artificial clouds. This usually happens above 26,000 ft where the ambient temperature is below -40°C.

As can be noticed on the picture above the intensity of the contrails vary with altitude / temperature, the bombers on the top right emitting heavier contrails than the planes at the bottom. A very important feature is that these early contrails are short lived. However modern jet aircraft with more powerful engines and high turbine temperatures emit more persistent contrails, which usually 'trail' for 20-30 miles along.

Contrails from a Quantas Boeing 747, Australia (Source: Wikipedia, contrails)

1 Air & Space Power Chronicles, Schweinfurt – the battle within the battle for the 8th US Air Force, Capt. D. Reichert, USAF

Contrails may have strange shapes and even be horizontally dispersed over large areas by jet streams, strong winds in the upper atmosphere that exceed a velocity of 100 knots.

2.2. DISTRAILS:

A distrail is the abbreviation for 'dissipation trail'. When an aircraft passes through a thin, stable cloud, even when the conditions for the production of contrails are not met, it produces a tunnel like path through that cloud.

Distrails are created as a result of the elevated temperature of the exhaust gases absorbing the moisture from the cloud. Clouds exist where the relative humidity is 100% and temperature and dew point are thus equal, but by increasing the temperature, the air can hold more moisture, so the relative humidity drops below 100% even for the same absolute moisture density, thus causing the visible water droplets in the cloud to be converted back into water vapor.

This picture shows a contrail that changes into a distrail at the top right, cutting through a layer of Altocumulus clouds.[2]

2.3. WINGTIP VORTICES:

Airplanes fly as a result of an equilibrium of lift, drag, mass and thrust. When a wing generates lift it causes a vortex to form at the wingtips and sometimes also at the trailing edges of the wing flaps. It causes wake turbulence, which is quite persistent and potentially dangerous to other, mostly smaller planes. The higher the angle of attack of the wing the higher the lift coefficient will be with stronger vortices in the end. High angles of attack in commercial aviation are achieved in landing configuration (flaps & landing gear down) or during initial climb after take off (high thrust & body angle).

The reduction in pressure and temperature across each vortex can cause water to condense and make the cores of these wingtip vortices visible. The effect is more common on humid days and in anticyclones with strong temperature inversions. These visible cores contrast with contrails and distrails, the latter being produced directly behind the engine at higher altitude.

Military aircraft travelling at transonic speed and making high performance maneuvers may produce a vapor cone or Prandtl-Glauert singularity as a result of a sudden drop in air pressure, sometimes nicknamed the shock collar or 'shock egg'.

2 Contrail science Home Page, http://contrailscience.com/contrail-to-distrail/

A U.S. Air Force F-22 'Raptor' executes a supersonic flyby at low altitude, producing pronounced wingtip vortices and a 'shock egg'.[3]

2.4. 'CHEMTRAILS':

Chemtrail is the contraction of 'chemical trail' and is used by some sources to denote intentional spraying by airplanes for military or political purposes and that may be harmful to public health. A more general name is 'aviation smog', which combines contrails, distrails and 'chemtrails'. Authors referring to chemtrails claim that this phenomena is much more persistent than contrails and when sprayed in a grid it is able to cover vast area's.

Although officially denied by government sources many countries performed tests for 'cloud seeding' to either generate precipitation where it was needed or to prevent precipitation where it is unwanted. At this moment only the Russian and Chinese governments admit that they use particular matter in order to manipulate weather patterns.[4]

This picture shows an interesting combination of contrails (right hand side), distrails (bottom left) and possibly 'chemtrails' (left hand side) over Belgium in the vicinity of Brussels, September 2009. Note that the contrails have spread over a large area.

[3] Live Science, Britt R.R., Editorial Director, June 30th 2009, Picture by courtesy of DOD/Petty Officer 1st Class Dejarnett, U.S. Navy.

[4] Michaels Jay, Meteorology News, 19th October 2009, 'Moscow testing cloud seeding'

3. CHARACTERISTICS OF CONTRAILS

The intuitive spirit is a gift from God. The rational brain is its servant. We have created a society that worships the servant and has forgotten the gift.

Albert Einstein (1879 – 1955)

3. CHARACTERISTICS OF CONTRAILS:

3.1. PREVIOUS SURVEYS ABOUT CONTRAILS:

Meteorologists ignore and even deny the effects of aviation on the weather, stating that contrails and in a lesser extend distrails only have an esthetic influence on the way the sky looks. As they do not induce precipitation nor reduce the visibility or affect sunshine they are not worth mentioning in a weather bulletin. On a few occasions meteorologists refer to it as veil shaped clouds, actually making the public belief that its origin is natural and not human. Because contrails are not considered as a weather phenomenon there are subsequently very few scientific surveys covering this topic.

Appleman was the first in 1953 to present charts that forecast the likelihood of contrail formation based upon the temperature profile of the 700–100-Hectopascal layer where commercial jets usually operate. [5] Pilie and Jiusto in 1958[6], Scorer and Davenport in 1970 [7] and Hanson & Hanson in 1995[8] modified his work. They identified a unique range within which a contrail should theoretically form.

However, the lack of field tests to verify these models and the fact that contrails have been noted to form and spread during conditions deemed unfavorable according to some of the models described above. With the introduction of new technology, such as satellites, more accurate surveys were within reach. This resulted for instance in the development of a new empiric model developed by Travis to predict widespread occurrences of contrails [9].

But even with the aid of geostationary satellites it proves extremely difficult to predict formation, size and life span of contrails that may remain isolated or cluster in groups. Extensive survey is mandatory in order to understand fully the nature of contrails. However there is an economic drawback to this, as aviation is the backbone of fast transport and commerce spanning the globe. Any survey can potentially be turned down by lobby groups that do not want to see unwanted attention unleashed on an ignorant public with undesirable side effects of aviation. Officially science does not work that way, but in practice researchers generally do not bite the hand that feeds them. This is also why contrails are politely classified as veil clouds.
Travis D.J, Carleton A.M. and Lauritsen R.G. performed a very interesting survey immediately after the 9-11 attacks in 2001, when all commercial aviation was stuck on the ground for a period of 3 days. It was probably the only opportunity to perform a comparative study. The results were only released two years later and proved the evidence of jet contrail influence on climate,[10] although it was suggested by some other researches that 'the sky was unusually clear during that period'.[11]

The results of some of these surveys are used in the next paragraphs.

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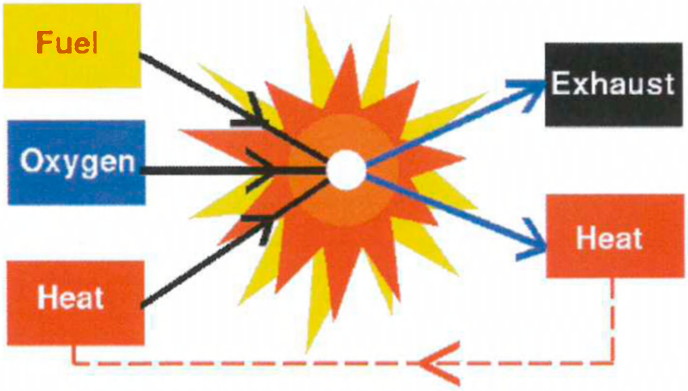
5 Appleman, H., 1953: The formation of exhaust condensation trails by jet aircraft. *Bull. Amer. Meteor. Soc.*, **34**, 14–20.
6 Pilie, R. J.. and J. E. Jiusto, 1958: A laboratory study of contrails. *J. Meteor.*, **15**, 149–154..
7 Scorer, R. S., and L. J. Davenport, 1970: Contrails and aircraft downwash. *J. Fluid Mech.*, **43**, 451–464..
8 Hanson, H. M., and D. M. Hanson, 1995: A reexamination of the formation of exhaust condensation trails by jet aircraft. *J. Appl. Meteor.*, **34**, 2400–2405.
9 Travis J.T, An Emperic model to predict widespread occurences of contrails, American Meteorology Society, Volume 36, Issue 9, September 1997.
10 Travis D.J., Carleton A.M. and Lauritsen R.G, Regional variations in U.S. diurnal temperature range for the 11-14 September 2001 aircraft groundings: evidence of jet contrail influence on climate, Journal of Climate, Volume 17, March 1st 2004.
11 Kalkstein and Balling Jr., Climate Research, 26, 1-4, 2004

3.2. CHEMICAL COMPOSITION OF CONTRAILS.

3.2.1. Standards for measurement:

In order to understand what is being done, we first have to understand some basic concepts. A jet engine is an internal combustion engine, just like an automobile engine is. In a jet engine, the fuel and an oxidizer combust (or burn) and the products of that combustion are exhausted through a narrow opening at high speed.[12]



The substances contained in a contrail depend on the following parameters:

- Engine type, its by-pass ratio and its pressure ratio & rated output: newer technology is usually much more environmentally 'friendly'.
- Type of fuel: modern jet engine fuel is primarily kerosene, which is a fossil fuel. However a distinction can be made between civil and military operations. Civil airplanes used in commercial aviation fly on JET A-1, while aircraft used for defense operate on a different fuel that provides optimal viscosity, heat sink and thermal stability in any operational theatre ranging from arctic to equatorial.[13] In this respect it is noteworthy that NATO-forces currently use JP-8 (Jet Propellant 8), a relative new fuel type whose additives are legally protected by a patent.
- Power setting: at take off power and cruise setting combustion is optimal, burning more than 99% of the fuel through complete combustion to carbon dioxide and water. At idle conditions, much less fuel is consumed and, in the interest of maintaining stable combustion at lower power conditions, some sacrifice in combustion efficiency occurs even though this inefficiency is still only a percent or so. Any combustion inefficiency of Hydrocarbon fuel will result in emissions of some combination of CO and incompletely oxidized Hydrocarbons, as well as some carbonaceous particles.[14]
- Maintenance standards and engine age: older engines or retrofitted power plants (e.g. upgrade to stage III of obsolete DC-8 aircraft in the years 2000 and beyond) emit significantly more pollutants than newer designs. Nano sized metal particles

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12 Picture by courtesy of Aerospaceweb.org.

13 Shawn P. Heneghan and William E. Harrison III, JP8+100: the development of high thermal stability fuel, Aerospace Mechanic Division, University of Dayton, OH and USAF Wright Laboratories, N. Wright Patterson AFB, OH, 6th international conference on stability and handling of liquid fuels, Vancouver, October 13-17 1997

14 Aircraft Engine Speciated Organic Gases: Speciation of Unburned Organic Gases in Aircraft Exhaust, Assessment and Standards Division Office of Transportation and Air Quality U.S. Environmental Protection Agency
and AEE-300 - Emissions Division Office of Environment and Energy Federal Aviation Administration, FAA publication. May 2009.

originating as a result of wear may also appear in the contrail. The same problem occurs in countries where maintenance standards are somewhat lower.

3.2.2. Chemical composition of jet aircraft emissions:

Burning fossil fuels primarily produces the following gaseous emissions:[15]

- Carbon Dioxide (CO_2).
- A large amount of water vapor (H_2O) that immediately freezes upon contact with the free air. This makes the contrail visible for the human eye.
- Nitric oxide (NO) and nitrogen oxide (NO_2), which together are called NO_x.
- Sulfur Oxides (SO_2).
- Soot.

However very few tests have been performed in order to assess and evaluate a detailed chemical composition in terms of Hydrocarbons (HC) of contrails. Of special interest is the survey of the US Environmental Protection Agency (EPA) and the Federal Aviation Agency (FAA) of May 2009, which uses data from a set of studies initiated by NASA called Aircraft Particle Emissions eXperiment (APEX). This project was supported by a wide range of sponsors (NASA, FAA, CARB, EPA, DoD ...) and focused attention on commercial aircraft Particulate Matter (PM) emissions.

The main objective of the APEX research was to characterize both gaseous and particulate emissions to advance the understanding of emissions from commercial aircraft engines. APEX1 was conducted in April of 2004 with a NASA-owned DC-8 aircraft equipped with CFM-56-2C1 engines. APEX2 was conducted in August 2005 for typical in-use aircraft engines (CFM56 engines on B737 aircraft), APEX3 testing was conducted in October and November of 2005 spanning a range of engines from a small business jet, through a modern regional turbofan, a single-aisle transport turbofan, to a large high bypass ratio turbo fan, representing five different engine types, some measuring more than one example. In all studies, exhaust plumes were sampled at the engine exit plane and several downstream measurement locations.

Test results on the CFM56-3 engines running on JET A-1 fuel revealed that the most important compound in emissions is Ethylene, followed by Formaldehyde, Acetylene, Propene, Acetaldehyde and another 46 substances including Benzene. The most important compounds of Hydrocarbon engine emissions on a molar basis are as follows:[16]

[15] NASA Facts, Glenn Research Center, Article FS-2000-04-010-GRC, Safeguarding our atmosphere, Glenn Research reduces harmful aircraft emissions.

[16] Shawn P. Heneghan and William E. Harrison III, JP8+100: the development of high thermal stability fuel, Aerospace Mechanic Division, University of Dayton, OH and USAF Wright Laboratories, N. Wright Patterson AFB, OH, 6th international conference on stability and handling of liquid fuels, Vancouver, October 13-17 1997 .

Compound	Emission Ratio (mmole / mole)	Compound	Emission ratio (mmole / mole)
Ethylene	0,770	Acrolein	0,061
Formaldehyde	0,572	l-butene	0,044
Acetylene	0,211	Glyoxal	0,044
Propene	0,151	1,3-Butadiene	0,044
Acetaldehyde	0,135	Benzene	0,030

The other 41 compounds have a weight below 0,030 mmole per mole. Full test results are included in appendix 1, page 6.

3.2.3. Impact of fuel specifications on aircraft engine emissions:

In commercial and military aviation the following fuel types are being used[17]:

FUEL TYPE	APPLICATION FIELD	REMARKS
JET A-1	Commercial aviation and some air forces not being a NATO-member (e.g. Austrian AF)	Jet fuel as analyzed in paragraph 3.2.2. nowadays also used in recreational aviation & flight training, referred to for fiscal purposes as Aero Diesel.
JP-4 Avtag	US Airforce, NATO Code F-40	50/50 Kerosene – Gasoline, phased out in 1996 in favor of JP-8.
JP-5	US Navy, NATO Code F-44	Still in use in naval operations, highest flash point, higher than JET A1 and JP-8.
JP-7	US Air Force	Specially designed for supersonic operations above Mach 3 (Example: former SR-71 Blackbird)
JP-8	US Air Force, NATO Code F-34	Replacing JP-4, transition should be completed by the year 2010.

Aircraft operators are constantly refining their fuels to deal with specific performance concerns. A major problem with gasoline is that it has what is known as a low "flashpoint." This is the temperature at which it produces fumes that can be ignited by an open flame. Gasoline has a flashpoint of around 30 degrees Fahrenheit (-1 degree Celsius). This makes fires much more likely in the event of an accident. So engine designers sought to develop engines that used fuels with higher flashpoints.

The U.S. Air Force during the 1990s switched from JP-4 to JP-8 because it had a higher flashpoint and was less carcinogenic, among other things. By the mid 1990s, the Air Force further modified JP-8 to include a chemical that reduced the buildup of contaminants in the engines that affected performance. JP-5 has even a higher flashpoint than JP-8, but its high cost limits its use to aircraft carriers. JP-8 has a strong odor and is oily to the touch, which makes it more unpleasant to handle and less safe in some ways.

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17 Air BP, the history of Jet fuel, www.bp.com.

Military personnel who work with it complain that it is difficult to wash off and causes headaches and other physical problems.[18]

Market is big and ever increasing with the military operations in Iraq, Afghanistan and the restless efforts on 'war on terror'. About 60 billion gallons (227 billion liters) were used worldwide by the late 1990s, with the U.S. Air Force, Army, and NATO using about 4.5 billion gallons (17 billion liters). It is also used to fuel heaters, stoves, powered electric generators, and combat vehicles. The M1 Abrams battle tank also uses JP-8 in its gas engine turbines. The use of a single fuel for most military applications would greatly simplify wartime logistics.

A latest development is JP-8+100, a version of JP-8 with an additive that increases its thermal stability by 56°C (100°F). The additive is a combination of a surfactant, metal deactivator, and an antioxidant. It was introduced in 1994. The additive reduces coking and fouling in engine fuel systems. Commercially, this additive is used in Boeing aircraft operated by KLM, and in police helicopters in Tampa, Florida. It is also used as fuel for Canadian CF-18 Hornets.

Of special concern is the comparison between JET A-1 and JP-8 / JP-8+100. Officially the fuel types are similar, except that the military variant contains additional icing inhibitor, corrosion inhibitors, lubricants, and antistatic agents.[19] A patent protects the exact composition of additives of JP-8, which is quite obvious in order to prevent espionage and transfer of technology to hostile parties.[20] Nevertheless it is possible to establish a comparison between Jet A-1 and JP-8+100 as several civil organizations are part of the engineering program.

More than interesting is the conclusion of the 6th International Conference on Stability and Handling of Liquid Fuel, held in October 1997 in Vancouver, Canada. In this paper the effects of the selected additives in JP-8+100 are examined on properties that are unrelated to thermal stability characteristics. For instance the comparison between Jet A-1 and JP-8 of additive 'Specific Aid 8Q405' is of special interest.[21] For a given concentration the conductivity of JP-8 jet fuel is much higher, which underlines the usefulness of the proposed additives. However one can logically assume that aircraft engine emissions will also significantly increase as a result of these additional icing inhibitor, corrosion inhibitors, lubricants, and antistatic agents. Official tests results have never been released by the US government, which is also the beneficiary of the patent.

The full paper of the 6th International Conference on Stability and Handling of Liquid Fuel, as well as the detailed specifications of military aviation fuels are included in appendix 2.

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[18] www.centennialofflight.gov/essay/Evolution_of_Technology/fuel/Tech21.htm

[19] MIL-DTL-83133F 11 April 2008 Superseding MIL-DTL-83133E 1 April 1999
Detail Specification Turbine Fuel, Aviation Kerosene Type, JP-8 (NATO F-34), NATO F-35, and JP-8+100 (NATO F-37).

[20] US patent 20050274063 – jet fuel additive concentrate composition and fuel composition and methods thereof, filed June 13th 2003, published December 15th 2005.

[21] B. Dacre and J. Hetherington, Electrical Conductivity of HITTS Additive Packages for the JP-8+100 Program, Rutherford Laboratory, Royal Military College of Science, Swindon, UK, 1997, Table 1, page 325.

3.3. AIRCRAFT EMISSION REGULATIONS:

3.3.1. Regulatory standards:

Engine emissions for civil aircraft are regulated. The UK Civil Aviation Authority publishes a databank with information on exhaust emissions of only those aircraft engines that have entered production. Engine manufacturers, who are solely responsible for its accuracy, provide this information based on a test run. It was collected in the course of the work carried out by the ICAO Committee on Aviation Environmental Protection (CAEP) but has not been independently verified unless indicated. The UK CAA is hosting this Databank on behalf of ICAO and is not responsible for the contents.[22] This already reveals two weak links:

- The manufacturer provides data, based on few tests. Its reliability is not verified by any agency. Therefore one must rely entirely on the quality system of that company.
- Military aircraft are actually exempted from this regulatory system as some aircraft are equipped with engines that are no longer used in commercial aviation.[23] Although aircraft equipped with older engines mostly do not have a noise certificate and are subsequently denied landing rights on civil airports they can still cross our airspace and land on AF Bases where those restrictions do not exist.
- As ICAO only publishes standards & recommended procedures, which must be integrated into national legislation, some countries can promulgate derogations on emission regulation.

The regulatory standards are those found in the Standards & recommended procedures of the ICAO, Annex 16, Volume 2 (subsonic engines), Part III and include a standard for smoke, unburned Hydrocarbons (HC), Carbon Monoxide (CO), Oxides of Nitrogen (NOx):

PARAMETER	**REGULATORY LEVELS[24]**
Smoke Number (SN)	$83{,}6 \times (F\infty)^{0{,}274}$ or 50, whichever is lower; and F∞ = rated engine output
Hydrocarbons (HC)	Dp / F∞ = 19,6; and Dp = mass in grams of any pollutant emitted during the reference landing and take off.
Carbon Monoxide (CO)	Dp / F∞ = 118
Oxides of Nitrogen (NOx)	Variable level in function of engine age and engine pressure ratio, ranging between DP / F∞ = 40 + 2∏∞ (production before 31-12-95) And DP / F∞ = 36 + 1,6∏∞ (engine pressure ratio 82,6 or more) And ∏∞ = engine pressure ratio

Refer to appendix 3 for a detailed explanation of these parameters.

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22 ICAO Aircraft Emissions Engine Databank, UK CAA, Updated July16th 2007.

23 Aircraft Engine Speciated Organic Gases: Speciation of Unburned Organic Gases in Aircraft Exhaust, Assessment and Standards Division Office of Transportation and Air Quality U.S. Environmental Protection Agency
and AEE-300 - Emissions Division Office of Environment and Energy Federal Aviation Administration, FAA publication. May 2009, page 3.

24 ICAO Aircraft Emissions Engine Databank, chapter 7, regulatory standards, UK CAA, Updated July16th 2007.

3.3.2. Case Study: civil versus military engine emissions.

3.3.2.1. Outline

The introduction of these regulatory levels was a good move to wipe out obsolete commercial jet Aircraft, unless the engine were retro fitted and upgraded to stage III.[25] Furthermore the databank includes data of engines, which do not have to comply with the emission standards, but instead received wide derogations. This clearly shows that this system is not fail safe, as it leaves too many backdoors.

In order to make a point let us examine more closely 3 different engine types:

a) The PW4048, new generation, which equips the Boeing 777.

b) The JT3D-3B that is still used on KC135 and B-52H bombers.

c) The CFM56-3C as used on the NASA APEX research as set in paragraph 3.2.2.

Engine tests on the Pratt & Whitney PW4084 as used on the Boeing 777 were performed from April 26th till May 2nd 1994 for the measurement of data for the ICAO data bank.[26]

The KC135 tanker, which is the military version of the Boeing 707, is equipped with JT3D-3B engines, tested between 1972 and 1974. Another version, the E-3 Sentry, better known as the Awacs (Airborne Early Warning and Control System), is equipped with TF33-PW100A of Inter Turbine Technologies, which are not included in the ICAO Aircraft Emissions Engine Databank.[27]

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25 Air Navigation (Aircraft Noise) Regulations, Statutory rules 1984 N°188 as amended, February 22nd 2002, Office of Legislative drafting, Attorny-General's Department, Canberra, Australia.

26 Boeing Photo, credit K63367-05

27 Image Courtesy of the United States Department of Defence

3.3.2.2. Test results

Comparison of aircraft emission data as obtained on the test data sheet between the three engine types reveals quite interesting information:

PARAMETER	PW4084 (Boeing 777)[28]	JT3D-3B (KC135 / B52H)[29]	CFM56-3C (APEX test)[30]
Smoke Number SN (standard 50)	10,50	54,50	9,9
Hydrocarbons HC (standard 19,6)	2,90	303,90	4,3
Carbon Monoxide CO (standard 118)	19,50	288,10	65,7
Oxides of Nitrogen NOx (standard 42,69 for KC135; 79,38 for B777; 23,35 for the APEX test engines)	62,80	34,30	53,1

The test results have to be interpreted as follows:

a) The data obtained with the CFM56-3C-1, labeled in green color in the table, acts as reference. This engine type meets all regulatory standards and will be used to establish the HC-emissions by the other engine types.

b) Older aircraft such as the KC135 tanker and the strategic bomber B-52H do emit substantial amounts of gaseous emissions. The NOx value of the JT3D-3B engine is lower than the data for the Boeing 777 engine due to its lower engine pressure ratio. To put in simpler words: the more engine power available the higher the emission of Nitrogen will be. This is considered as normal.

c) For some unknown reasons derogation for the JT3D-3B engine has been granted in the ICAO data sheet (see appendix 3): 395,4 for the HC-parameter and 328,2 for CO. <u>This is in fact an increase of a very royal 2017,6% for the emission of Hydrocarbon and 278,2% for Carbon Monoxide.</u>

d) If one extrapolates the test results as published in paragraph 3.2.2 for the CFM56-3C engine the actual weight of each chemical compound is magnified by an unknown factor. One can assume that for instance the emission of Ethylene could well exceed a hundredfold the test data of 0,77 emission ratio in mmole / mole (see appendix 1). There is no doubt that operation of airplanes with such obsolete engines has a negative influence on public health.

e) Apart from some minor airline companies on remote places the JT3D-3B engine is exclusively in use in military forces that are not subject to any restrictions of that kind. Although no data is available for engines used on the E-2 / E-3 Sentry 'Awacs' model one can assume that its emissions are similar, because some air forces such as the Royal Air Force, the French Armée de l'Air and the Saudian forces already have retrofitted their E-3's with more contemporary CFM-engines.

Copies of the ICAO documents for the 3 engine types can be found in appendix 3.

[28] ICAO Engine Exhaust Emissions Databank, Subsonic Engines, PW4084, July, 18th 2007.
[29] ICAO Engine Exhaust Emissions Databank, Subsonic Engines, JT3D-3B, October, 1st 2004.
[30] ICAO Engine Exhaust Emissions Databank, Subsonic Engines, CFM56-3C-1, October, 1st 2004.

3.3.2.3. Production numbers of the KC-135 Stratotanker:

In order to know if excessive emissions of these military aircraft are statistically significant one must assess how of them have been build and the percentage of military traffic in global aviation. Production of the KC135 ceased in 1965. In 1988 Boeing Company performed a mid life upgrade on 746 airplanes, clearly denoting the long active service of that airplane.[31] About 410 airframes have been upgraded since with CFM56 engines.[32]

Additionally a batch of 33 E-3 Sentry aircraft has been build of whom 17 are in use in NATO forces. These aircraft, which have not been retrofitted with CFM-engines[33], operate mainly from Geilenkirchen AFB (German – Dutch border) with a multinational crew under Luxemburg flag with apparently a civil registration number. The reason for this is quite complex. In summary official NATO sources state that it is not possible to use markings of all member countries and they had to find a member nation 'whose legislation in this area was sufficiently accommodating to provide the Force Commander with enough latitude and flexibility to make up his crews as required and organize maintenance operations'.[34] Thus Registration of the E-3As with NATO's smallest member nation, Luxemburg, was proposed.

Note the flag of Luxemburg on the tail section and underneath the wing of this E-3A at Geilenkirchen AFB. Its registration number is a civil LX-code. This airplane is still equipped with older TF33-PW100A engines (credit: official NATO AWACS website).

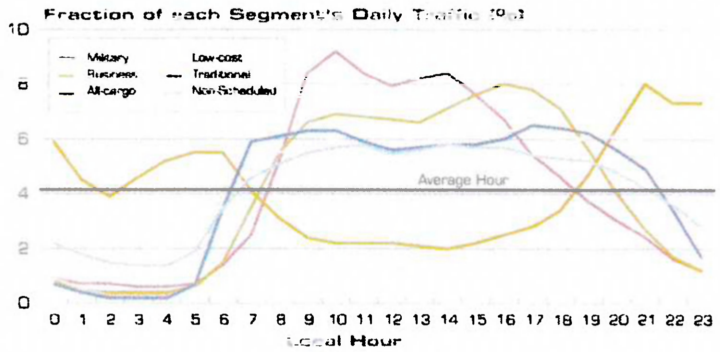
It is quite intriguing that airplanes with a Luxemburg (semi) civil registration do not need to comply with the ICAO engine emission databank and can do things at their own convenience. Furthermore Mr. D. Rumsfeld, former minister of defense under the Bush administration, declared that an upgrading program of the B-52 and KC-135 would only be partly implemented as a result of cost cutting programs.[35] A NATO survey suggests that the Awacs aircraft are 'sustainable beyond 2025'.[36] These old aircraft with high HC- and CO-emissions are likely to stay in the air for a while. The fact that Geilenkrichen AFB will not be closed in the year 2025 as planned but even see its runway extended underlines

[31] Boeing Integrated Defence Systems website, Stratotanker overview.
[32] CFM News, USAF expands CFM56-2-powered RC-135 fleet, July, 22nd 2002.
[33] CFM News, USAF expands CFM56-2-powered RC-135 fleet, July, 22nd 2002.
[34] Official NATO Airborn Early Warning and Control Force website www.e3a.nato.int, E-3A Component, FAQ, Question 14 'Why is there a red lion on the tail?'
[35] Global Security, SECAF lays out case for tanker upgrade, Master sgt S. Elliott, Air Force Print News, March 7th, 2003.
[36] NATO Airborne Early Warning and Control Program, US Air Force Maj. Gen. G. Winterberger, NAEW&C Force Commander and P. McCaffrey NAPMA, Plans and Evaluation Division, March 2nd, 2005.

this.[37]

3.3.2.4. *Percentage of military traffic in global aviation:*

Although the majority of air traffic on this planet is civilian, military operations represent almost the most important segment in aviation[38]:



According to the Eurocontrol statistics military traffic is actually the biggest segment between 8 AM and 3 PM. Of course not all military traffic consists of KC-135 tankers and E-3 Sentry aircraft, but one must bear in mind that very substantial resources in an Air Force are used to keep the Defense Force (Multi Role Units & Ground units in crisis zones) operational and this includes a lot of logistics in the form of transport wings. This does not only include modern aircraft as the C-17 Globemaster but also obsolete planes as the Lockheed C-130, which is still in use in many Air Forces and is not subject to study in this survey.

However, when taking into account that some part of civil cargo traffic is performed on behalf of the military then we can assume that the military segment tops above 10% at regular intervals.

3.3.2.5. *Conclusions of this test case:*

The logical conclusion obtained by combining the data as mentioned above is that the military segment is statistically important and that airplanes with excessive HC-, CO- and NOx-emissions are still widely used, although airplanes such as the KC135 and E-3 'comply' with ICAO-Standards and Recommended Procedures.

This is actually unacceptable in the view of the efforts being made by civil operators in order to comply with environmental requirements. Efforts should be made by politicians to phase out those aircraft equipped with engines that do not meet the basic regulatory levels as set in the ICAO. This encompasses the workforce of about 300 KC-135 in the United States and all of the E-3 Sentry aircraft based at Geilenkirchen. In this respect it is a total contradiction that these aircraft are allowed to operate under a Luxemburg LX-registration number, bearing in mind that its engine types are even not listed in the ICAO-databank.

[37] De Limburger, Limburgs dagblad, 'Basis Awacs blijft ook na 2025 gewoon open', December 15th, 2009.

[38] Eurocontrol Trends in Air Traffic, Volume 5, Dependent on the dark: cargo and other night flights in European Airspace, 2009.

4. EFFECTS OF CONTRAILS ON CLIMATE

No more than a few decades remain before the chance to avert the threats we now confront will be lost and the prospects for humanity immeasurably diminished. We, the undersigned members of the world scientific community, warn all humanity what lies ahead. A great change in the stewardship of the Earth and life on it is required if vast human misery is to be avoided and our global home on this planet not to be irretrievable mutilated.

"World Scientists, warning to humanity", document signed by 1600 senior scientists from 71 countries, published in Time, Planet of the Year, November 18th 1992,

Publication rejected by the New York Times and Washington Post as not newsworthy

4. EFFECTS OF CONTRAILS ON CLIMATE:

4.1. Effects of contrails on cloud formation:

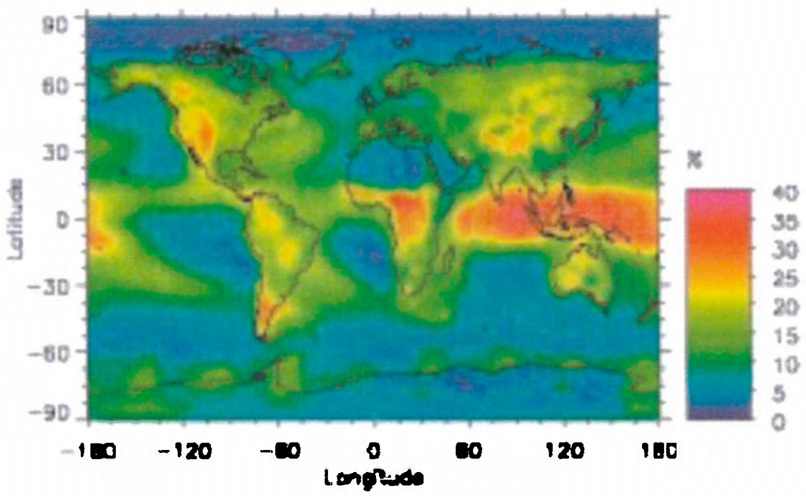
4.1.1. Characteristics of Cirrus clouds:

Cirrus clouds (WMO abbreviation Ci) are formed in a natural way when water vapor freezes into ice crystals at altitudes above 8000 meters (26,000 ft) in the higher part of the troposphere. The exact altitude depends also on the height of tropopauze, the boundary with the stratosphere and the higher levels of earth's atmosphere. That means that Cirrus clouds in polar regions will appear at a much lower altitude than at the equator.

Due to the sparse moisture at a high altitude, Cirrus clouds are very thin. Fall streaks, sometimes also called Virgae, form when ice crystals fall from Cirrus clouds. The change in wind with height and how quickly these ice crystals fall determine the shapes and sizes the fall streaks attain. Since ice crystals fall much more slowly than raindrops, fall streaks tend to be stretched out horizontally as well as vertically. Cirrus streaks may be nearly straight, shaped like a comma, or seemingly all tangled together. As wind velocity increases with altitude they may be spread over large areas. This is particularly the case in the vicinity of jet streams, which splits the cells of the different tropopauze layers. Sometimes one can even see the clouds moving fast from the ground.[39]

There are other cloud types associated with Cirrus such as the Cirrostratus (WMO abbreviation Cs) and the Cirrocumulus (WMO abbreviation Cc), but these are generally related to incoming frontal systems and are further omitted from this survey.

Although Cirrus clouds look thin they may occupy a significant part of the sky up to 30% and even more in some areas – in meteorological terms called 'scattered' (SCT) up to 'broken' (BKN). Transmittance of direct and diffuse sunlight is about 80%.[40]



Global map of average Cirrus cloud cover based on the ISCCP cloud database for the period 1984 - 1999 (in % cloud cover)

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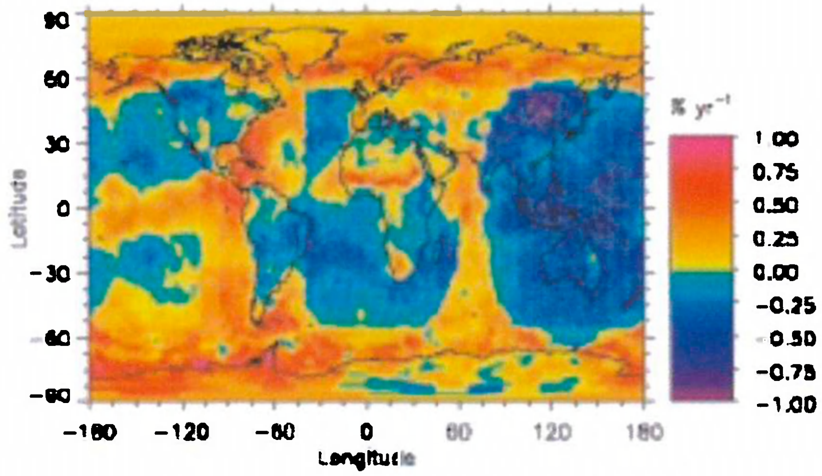
[39] WMO website, Meteoroligical Codes for high altitude clouds.

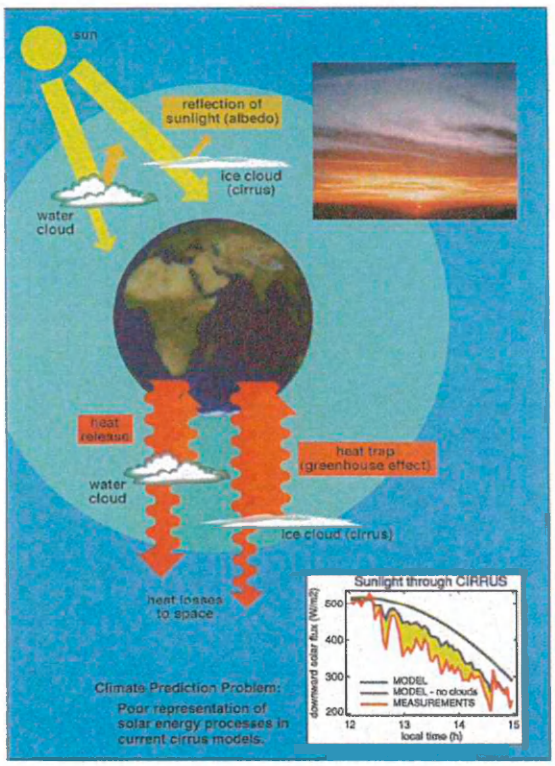
[40] Is there a trend in Cirrus cloud cover due to aircraft traffic?, F. Stordal et al., Atmos. Chem. Phys., 5, (2005) 21555-2161.



Changes in the Cirrus cloud cover in percentage between the two periods 1992-1999 and 1984-1991.[41]

4.1.2. Impact of Cirrus clouds on climate:

The climate of the Earth results from an energy balance between absorbed sunlight and radiative losses of heat from Earth and its atmosphere to space. Clouds are an important modulator in this balance. Clouds reflect sunlight back toward space, which reduces the solar energy available to the Earth – also called the Albedo effect. Clouds also reduce radiative heat losses to space (greenhouse effect). Which of these two opposing processes dominates depends on many parameters including cloud particle composition, cloud structure, cloud cover, and cloud location. Changes to only one of these parameters can have significant implications for climate.[42]



41 Idem as footnote 40.

42 Kinne S., Cirrus Clouds and climate, NASA Ames Research Center webpage.

The greenhouse effect is weak for low altitude clouds, so their Albedo effect dominates and they cool the Earth's climate. In contrast, cold high altitude Cirrus clouds may either cool or warm the climate. This will prove to be a key element whether to determine if weather modification programs are being conducted on the planet in order to reduce 'global warming'.

Cirrus clouds have thus a strong greenhouse effect, which may outweigh their Albedo effect losses. As the importance of both opposing effects depends critically on little understood Cirrus properties, theoretical calculations of the climatic effects of Cirrus are controversial. The main uncertainty stems from a current inability to calculate the scattering of sunlight in Cirrus clouds, since they contain a multitude of ice crystal shapes and sizes, and are irregular in structure. Even more, Stefan Kinne of the NASA Ames Research Center states clearly that the Cirrus Albedo effect is severely underestimated by calculations.[43]

This proves that knowledge in this field of science is quite limited and extensive research is mandatory in order to fully understand the impact of Cirrus clouds on climate. In this respect it is noteworthy that evidence of thin Cirrus clouds in the Stratosphere has already been established.[44]

4.1.3. Development of contrails into Cirrus clouds:

Contrails, a man made phenomena, are not listed as such in the WMO cloud coding. In the high cloud section of the document the only possible link with contrails is the 'Cirrus in the form of hooks, filaments, or both, progressively invading the sky' – WMO code 0509, section 4. Refer to appendix 4 for the full cloud coding as provided by the WMO.

Because contrails are not listed in the WMO decoding table there is logically no instrument to catalogue them or to make them an inherent part of a weather forecast (TAF in aviation). When contrails turn into Cirrus clouds they are just incorporated in the actual weather report (METAR in aviation). As there are no instruments for measurement most meteorologists just limit their impact on climate as being only 'esthetic'.

Not all contrails develop into Cirrus clouds and if they do, what is the exact scientific base? Well, aircraft emissions as explained in paragraph 3.2.2. are actually aerosols, microscopic particles suspended in the air.[45] They act like seeds: water molecules can condense or freeze on to them to form cloud particles.

Sulpheric Acid (H_2SO_4) increases as a result of gas-phase oxidation processes. Soot particles become chemically activated by adsorption and binary heterogeneous nucleation of Sulphur Trioxid (SO_3, a chemical compound of Sulphur and Oxygen) and H_2SO_4 in the presence of H_2O, leading to the formation of a partial liquid H_2SO_4/H_2O coating. Upon further cooling, volatile liquid H_2SO_4/H_2O droplets are formed by binary homogeneous nucleation, whereby the chemi-ions act as preferred nucleation centers. These aerosols grow in size by condensation and coagulation processes (clotting).

Coagulation between volatile particles and soot enhances the coating and forms a mixed H_2SO_4/H_2O-soot aerosol, which is eventually scavenged by background aerosol particles at longer times. If liquid H_2O saturation is reached in the plume, a contrail forms. Ice particles are created in the contrail mainly by freezing of exhaust aerosols. Scavenging of exhaust particles and further deposition of H_2O leads to an increase of the ice mass. The

43 Kinne S., Cirrus Clouds and climate, NASA Ames Research Center webpage.
44 Keckhut P., Hauchecorne A., Bekki S., Colette A., David C., and Jumelet C., Evidences of thin Cirrus clouds in the stratosphere at mid-latitudes, Service d'Ae'ronomie/Institut Pierre-Simon Laplace, CNRS, Verrie`res le Buisson, France, Received: 28 December 2004 – Accepted: 17 January 2005 – Published: 21 June 2005
45 NASA Facts, Glenn Research Center, Article FS-2000-04-010-GRC, Safeguarding our atmosphere, Glenn Research reduces harmful aircraft emissions.

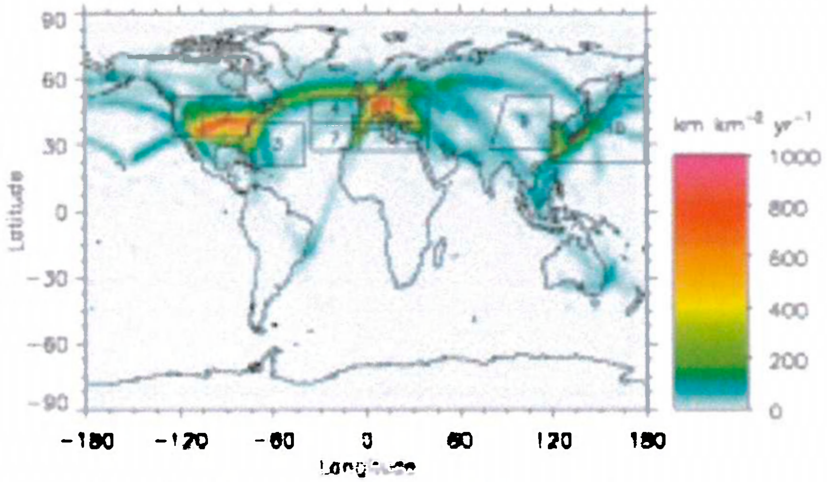
contrail persists in ice-supersaturated air and may develop into a Cirrus cloud. Short-lived and persistent contrails return residual particles into the atmosphere upon evaporation. The scavenging timescales are highly variable and depend on the exhaust and background aerosol size distributions and abundances, as well as on wake mixing rates.

This means that the formation of contrails not only depend on the amount of HC-, CO and NOx engine emissions but also on the fuel type being used. In this respect it is likely that older engines operating on fuels with additional additives as highlighted in the case study produce more persistent contrails.

4.1.4. Impact of aviation on the formation of men made 'Cirrus':

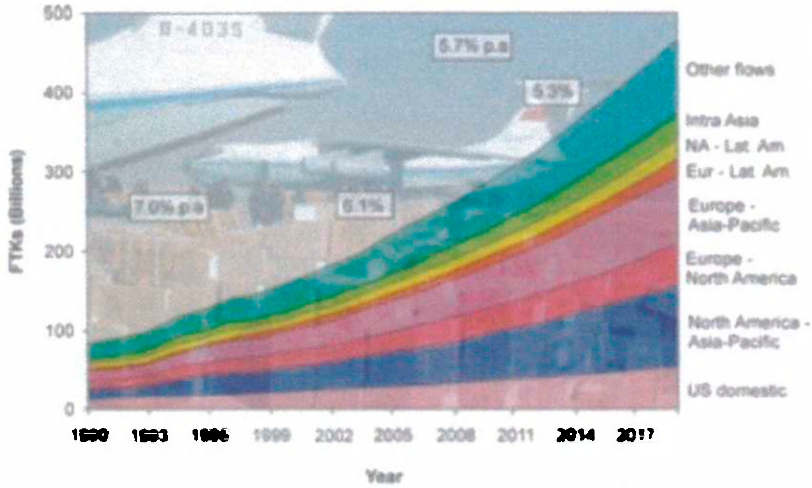
Before discussing the possible impact of contrails on climate one has to assess the most popular flying routes as well as the projected evolution of aviation on the globe.

The most congested traffic patterns are situated between the East and West coast of the United States, overhead the North Atlantic and between major cities in Europe. When we look at the trend in commercial aviation the number of flights may well double in the next ten years. In order to avoid airspace saturation on the busiest routes Air Traffic Control agencies such as CANAC in Brussels anticipated this development by introducing new transponders (Mode S) in November 2009 to allow smaller separation standards between airplanes.



This map shows the distances flown with aircrafts for the year 2000 between 9800 and 11600 m altitude. It shows also 10 regions from which a correlation between aircraft density and Cirrus trends has been analyzed and proven. [46]

[46] Is there a trend in Cirrus cloud cover due to aircraft traffic?, F. Stordal et al., Atmos. Chem. Phys., 5, (2005) 21555-2161.



This graph shows the projected growth in freight in freight ton kilometers (FTK), according to estimation from Boeing Corporation in 2002.[47]

The predicted increase in air traffic for the year 2009 has been hampered by the worst financial crisis since the great depression in the thirties, but it still at its 2007 level – an increase of about 28% in comparison to the year when the above graphics have been designed.

According to the Quantify Project Group, which studies the climate impact of transport systems in Europe, the amount of Cirrus clouds tends in general to decrease on our planet, except in regions with high air traffic. For Europe it is estimated that the amount of Cirrus clouds, which can be attributed to air traffic increases by 1-2% per decade. Aviation induced cloud cover is maybe 3-5% over Europe.[48]

According to the same source there are trends observed that increase in Cirrus cloud cover and in the fuel used by aircrafts go parallel. However, the consumed fuel increases over the years less fast (33% for 1992 to 2000) than the distance traveled by plane (+44%) since engines became more efficient. Military air traffic has also significantly increased since the second Gulf war and the subsequent 'war on terror' – putting reserve squadrons of the National Guard with older technology back in action.

Whiteleg and Cambridge from the Stockholm Environment Institute even expressively states that aviation poses a threat on different stakeholders:[49]

- On global level: affecting whole eco-systems.
- Regional: e.g. the European theatre.
- Local: e.g. living in the vicinity of Frankfurt airport.
- Community: living in the immediate surrounding of Frankfurt airport.
- Health impact: possible diseases on all levels.

[47] Whiteleg J and Cambridge H, Aviation and Sustainability, Stockholm Environment Institute, 2004.
[48] EU FP6 Integrated Project Quantify, Quantifying the climate impact of global and European Transport Systems., 2006.
[49] Whiteleg J and Cambridge H, Aviation and Sustainability, Stockholm Environment Institute, 2004, page 15.

GLOBAL	REGIONAL	LOCAL	COMMUNITY	HEALTH IMPACT
Carbon Dioxide	**Contrails**	Sulphur Dioxide	Noise exposure	**Pulmonary disease**
Cirrus cloud formation	Acidification	Ozone	Sleep disturbance	**DVT – Deep Vein Thrombosis**
Nitrogen Oxides	Potential loss of habitat	Airport pollution	Building damage	**Radiation exposure**
Climate change	Reduction in biodiversity	Local traffic congestion	Rural disturbance	
Ozone depletion		**Particulate matter (PM)**	Poorer education performance	
Global warming				

Contrails and formation of Cirrus clouds were thus in 2004 already 'known' problems. However no action of any kind has been taken to solve this issue. The situation is even worse: international aviation emissions are excluded from the Kyoto Protocol and therefore aviation 'enjoys the freedom to continue to pollute the atmosphere'. It has now been recognized by the UK government (HMSO, 2004) that if aircraft emissions are taken into account, it will not be able to meet its target of 60% reduction in greenhouse gases by the year 2050.[50]

There are other hints that any effort to reduce jet engine air emissions and subsequent pollution is systematically torpedoed for the sake of global economy. For instance the Reuters news agency reported on November 23rd 2004 that local air pollution agencies in the United States were pulling out of talks with the U.S. Environmental Agency and the Federal Aviation Administration after 5 years of work with no acceptable results. The aim of this voluntary program was to develop a scenario for reduction of pollution and particulate matter (PM) of jet aircraft.[51] Recently some new surveys have been conducted in order to develop acceptable scenarios with a minimum financial impact on companies for contrail control. For instance Robert Sausen of the DLR-Institute for physics of the atmosphere in Germany suggested a change in cruising altitude of commercial airplanes, with the best option a reduction of 6000 ft.[52] However reducing the cruising altitude would signify a noticeable increase in fuel consumption. It does not come as a surprise that these initiatives are kept silent for the sake of return on investment, which is very low to negative in the sector ('Start with a big fortune in aviation to acquire a small one').

It is undeniable that aviation has a significant impact on climate and some scientists agree that it has not been quantified. Sausen even describes in this survey the level of scientific

[50] Same source as footnote 48, page 17.
[51] Truth in aviation: efforts to reduce jet engine air pollution take a set back, Newsletter of the Regional Commission on Airport Affairs, December 2004.
[52] Sauser R, Climate impact by aviation and minimising it by operational means, DLR-Insttitut für Physik der Atmosphäre, Oberpfaffenhofen, Germany, meeting on environmental impact of air traffic, Brussels, May 3rd 2007.

knowledge on Cirrus clouds and contrails as 'poor'. Refer to appendix 5 for an updated aviation radiative forcing for the year 2000.

A different pathway is the introduction of a carbon tax on aviation operations. Besides the fact that it would be a very profitable operation for some interest groups it is clear that many airline companies would be forced to file for bankruptcy if a carbon tax would be levied on their operations, resulting in a net loss of 4 million jobs in the United States alone.[53] Also other countries such as Australia and India have objected against such tax and even if the European Community votes such a law it would not only be delayed significantly by rearguard battles, but low cost flying would certainly be a thing from the past.

Bearing in mind that the Copenhagen summit in 2009 was deliberately torpedoed by the main industrial nations with the United States on top one can only conclude that the ongoing scenario is to develop options that ensure 'Business as Usual'. Even the Kyoto Protocol can be considered as mere occupation therapy for the development of a lucrative cap & trade system.

4.2. EFFECT OF CONTRAILS ON TEMPERATURE:

4.2.1. Variations in the daily temperature range as a result of contrails:

Although it is clear that aircraft emissions have an impact on climate it is quite difficult to measure this, because aviation is just part of everyday life. However there has been one small window of opportunity to perform a reliable scientific survey, at the time that all commercial flights within the U.S. airspace were grounded for a period of 3 days after the events of 11 September 2001.[54]

This survey, performed by David J. Travis, Andrew M. Carlton and Ryan G. Lauritsen, released in final form 2 years later (!), revealed a departure of average diurnal temperature range (DTR) from the normal values derived from the 1971 – 2000 climatology data for the indicated 3-day period in 2001. DTR values for 11 to 14 September during the grounding period, measured at stations across the United States, show an increase of about 1,1°C in comparison with the normal values.[55]

This increase is larger than any during the 11–14 September period for the previous 30 years, giving ammunition to critics who state that weather conditions at this specific period were very extraordinary and no scientific based conclusions could be taken. However even more surprising is the fact that the 11-14 September increase in DTR was more than twice the national average for regions of the United States where contrail coverage has previously been reported to be most abundant, such as the Midwest, Northeast and Northwest regions.[56]

In the subsequent days after September 14th when civil flight operations resumed there was a temperature drop of about 0,8°C, denoting the return to 'normal' conditions. This underlines the impact of contrails on global surface temperatures with a noteworthy cooling down effect, especially reducing the maximum day temperatures. A new proof that aviation significantly affects climate emerged after the massive grounding in Europe in

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53 Kreutzer D, Ph.D., The economic impact of cap and trade, testimony before the energy and commerce commitee U.S House of Representatives, April 22, 2009.
54 Nature, Volume 418, August,8 2002, Contrails reduce the daily temperature range, a brief interval when the skies were clear of jets unmasked an effect on climate.
55 Travis D.J., Carleton A.M. and Lauritsen R.G, Regional variations in U.S. diurnal temperature range for the 11-14 September 2001 aircraft groundings: evidence of jet contrail influence on climate, Journal of Climate, Volume 17, published March 1st 2004.
56 DeGrand J., Carleton A.M., Travis D.J. & Lamb, P.J. Appl. Meteorol, 39, 1434-1459, published in 2000.

2010 due to the volcano eruption in Iceland. It is too early to assess the quality of the survey, but the Kings College in London claims that 'airports are air polluters'.

The full paper covering the regional variation in U.S. diurnal temperature range during the 9-11 events, the summary from the magazine 'Nature' as well as the press release of April 22nd, 2010 from the Kings College London can be viewed in appendix 6.

4.2.2. Global warming potential of aircraft engine emissions:

After the first reports of 'Climate Gate', the deliberate manipulation of weather data for IPCC purposes that emerged on the surface during the Copenhagen summit for climate change in 2009, one can even wonder if there is any global warming at all[57]. Climate change is a more appropriate term.

Nevertheless the potential of global warming of gaseous emissions from aircraft engines is not to be neglected. Global warming potential (GWP) is the impact a greenhouse gas has on global warming expressed over a 100-year time period. The GWP of each greenhouse gas depends on its ability to absorb heat in the atmosphere. By definition, CO_2 is used as reference case, with a GWP of 1.

Global warming potential values enable an increase or reduction of any of the greenhouse gases to be expressed as an equivalent reduction of CO_2 over a 100-year period. Table 4.2.2-1 lists the GWP of the greenhouse gases covered by Kyoto as well as those others related to aviation emissions:[58]

Greenhouse gas	Chemical formula	GWP 100 year time horizon
Carbon Dioxide	CO_2	1
Methane	CH_4	21
Nitrogen Oxide	N_20	310
Perfluorobutane	C_4F_{10}	7000
Perfluorocyclobutane	$c\text{-}C_4F_8$	8700
Sulphur Hexafluoride	SF_8	23900

The GWP of greenhouse gases is quite high. According to the study of the Stockholm Environmental Institute aviation emissions account for around 3.5 per cent of man's contribution to global warming from fossil fuel use. By 2050, this percentage could grow to between 4 per cent and 15 per cent (IPCC data from1999 and provided the data is not corrupted by 'Climate Gate'.).[59]

However this global warming potential is not realized as can be concluded in the post 9-11 survey. There are three possible reasons for this:

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57 Climate change: this is the worst scientific scandal of our generation, Daily telegraph, November 28th 2009.

58 Intergovernmental Panel on Climate Change, Climate Change 1995: The Science of Climate Change (Cambridge, UK: Cambridge University Press, 1996), Table 2-9, "Radiative Forcing of Climate Change," p. 120.

59 Whiteleg J and Cambridge H, Aviation and Sustainability, Stockholm Environment Institute, 2004, page 17

- The cooling down effect due to the formation of contrails and subsequent 'Cirrus' outweighs the Global Warming Potential of the gaseous engine emissions. There are no known scientific studies on this topic.
- Additional additives have been incorporated in jet fuel in order to counter global warming.
- A combination of both scenarios.

As will be explained in a different paragraph several patents and scientific research papers exist for cloud seeding in an attempt to counter global warming.

4.3. EFFECT OF CONTRAILS ON PRECIPITATION:

4.3.1. Precipitation principles:

Precipitation occurs when the following conditions are met:

- There must be moisture in the air. A cold parcel of air can contain less moisture than warm air. Relative humidity increases when the air parcel is adiabatically cooled (e.g. orographic lifting) or moisture is added to that parcel (e.g. air mass picking up moist from an ocean) or a combination of both.
- Condensation nuclei, such as dust particles, must be abundant.
- The droplets or ice crystals must be heavier than the updrafts. Mounting air currents are a result of instable air (cold air moving in over a warmer surface) and produce cumuliform clouds, the Cumulonimbus or Thunderstorm being its supreme form. The higher the updrafts the more violent the precipitation will be. In stable weather conditions the droplet tends to fall as soon as it is formed due to the limited updrafts.

Moreover precipitation is much more likely in low-pressure areas where frontal systems are allowed to slip in. However thermal thunderstorms may develop at any place on earth, except at the poles where temperatures do not permit this. A new development in climate change is the introduction of super cells with deep rotating updrafts that bust through the stratosphere, with extensive hail and extreme turbulence as a result. The crash of Air France flight 447 on its way from Rio de Janeiro to Paris in June 2009 with the loss of 224 lives is probably attributed to the presence of such cell on its flight path.

4.3.2. Relation between contrails, air temperature and precipitation:

The question arises if contrails and their switch into men made Cirrus have an impact on precipitation. In that respect 3 counter posing elements have to be distinguished:

a) Jet engine emissions with extensive aerosol production deliver quite some condensation nuclei on which droplets can form. This increases the probability of additional precipitation.

b) However as shown in the survey in paragraph 4.2.1 a significant temperature drop is noted due to the formation of contrails. As cold air can contain less moisture than a warm parcel of air precipitation could decrease.

c) Because Contrails are formed in the upper part of the troposphere the subsequent reduction in temperature could trigger additional instability in the atmosphere. For example an ascending air particle in a Cumulonimbus cloud would indeed meet almost no resistance when nearing the tropopauze because it is always warmer than the surrounding air. As a result it will bust through the tropopauze and enter the stratosphere. Only the isothermal layer in the stratosphere prevents the thunderstorm shooting much higher. To put it in different words: contrails may induce the formation of super cells. Very limited scientific field research has been performed on that topic, but this conclusion is only a matter of logic.

It is clear that there is a relation between these parameters, but scientists have failed to quantify the parameters. This is nothing new in meteorology: since the introduction of the Bergeron-Findeisen precipitation theory in 1935 it has been continuously evaluated and criticized[60], but scientists can still not determine why a single cumulus develops into a thunderstorm while its neighbor doesn't.

The same applies in this discussion. A survey by Yun Qian and his colleagues, published in 2009, revealed long-term observational data that both the frequency and amount of light rain have decreased in eastern China for 1956–2005 with high spatial coherency and this as a result of increased aerosol concentration in the atmosphere.[61] Aviation has not been particularly targeted in this survey, but aircraft engine emissions have to be considered as a variant on this.

Professor D. Rosenfeld of the Institute of earth Sciences at the Hebrew university of Jeruzalem (Israel) has come up with a surprising finding to the disputed issue whether air pollution increases or decreases rainfall. The conclusion of the study group is as follows: both can be true, depending on local environmental conditions. The amount of aerosols is the critical factor controlling how the energy is distributed in the atmosphere.[62] According to this survey they followed the energy flow through the atmosphere and the way it is influenced by aerosols and other 'airborne' particles. On this planet there is indeed an interaction of energy between the different cells within the troposphere in order to obtain a life sustaining temperature (15°C in the International Standard Atmosphere at sea level).

Aerosols act twofold: on one hand they act like a sunscreen reducing the amount of energy reaching the ground. Accordingly less water evaporates and the air mass at ground level stays cooler and drier, with a reduced tendency to rise and form clouds.

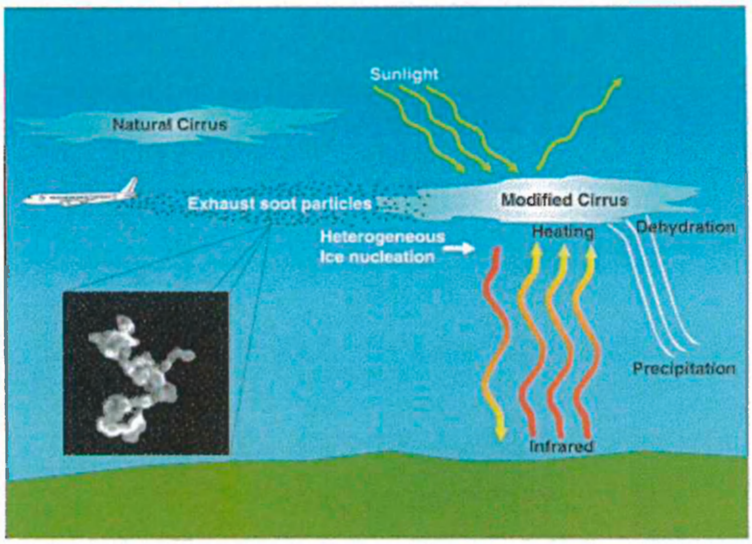

Figure 1: Ice cloud microphysical model

Aerosols act as a sunscreen with a subsequent reduction of energy reaching the ground. Some sources refer to this phenomenon as 'global dimming'.[63]

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[60] Stickley A.B., An evaluation of the Bergeron-Findeisen precipitation theory, Monthly Weather Review, October 1940.

[61] Qian, Y., D. Gong, J. Fan, L. R. Leung, R. Bennartz, D. Chen, and W. Wang (2009), Heavy pollution suppresses light rain in China: Observations and modeling, *J. Geophys. Res., 114*, D00K02, doi:10.1029/2008JD011575.

[62] Rosenfeld D, Does air pollution increase rainfall?, Hebrew University of Jeruzalem, September 5th 2009.

[63] geo.arc.nasa.gov/sge/jskiles/fliers/gif_folder/image10/image10a.gif

On the other hand, without natural aerosols such as dust particles there would be no cloud droplets because they act as gathering points for air humidity, the so called condensation nuclei as explained in the previous paragraph. When the droplet is formed, energy is released in the form of heat during the condensation process. This energy level for the evaporation – condensation process is significantly higher than during the freezing / melting process (540 Calories /g versus 80 Calories /g). Due to the released heat the air parcel gets lighter than the surrounding air and is allowed to rise further. However, if there is a surplus of these condensation nuclei as a result of natural activity (e.g. Vulcan eruption) or men's intervention (e.g. industrial pollution, contrails), the droplets never reach the critical mass needed to fall to earth as precipitation because there is just not enough water to share between all the aerosol particles. Furthermore with a rising number of droplets their overall surface increases, which on turn increases the amount of sunlight reflected back to space with subsequent cooling and drying of the Earth.

In a nutshell the study of Prof. Rosenberg shows the following: with rising pollution, the amount of precipitation at first rises, then maxes out and finally falls off sharply at very high aerosol concentrations. Of even more interest is his conclusion: 'The practical result is that in relatively clean air, adding aerosols up to the amount that releases the maximum of available energy increases precipitation. Beyond that point, increasing the aerosol load even further, lessens precipitation.' This opens of course an interesting window towards future climate control by regulating the amount of aerosols that are released in the upper troposphere. To put it in the words of Prof. Rosenberg: 'The determination of this issue is one with significant consequences in an era of climate change and especially in areas suffering from manmade pollution and water shortages, including Israel'. This is indeed very true: domestic water supplies are the emerging assets on Earth. The outline of the survey of Prof. Rosenberg can be found in appendix 7.

4.4. OTHER EFFECTS OF CONTRAILS:

4.4.1. Dehydration of the stratosphere due to contrails:

The extreme dryness of the stratosphere is believed being caused by freeze-drying of air as it enters the stratosphere through the cold tropical tropopause. Sedimentation of ice crystals in the thin Cirrus may provide a significant downward flux of water vapor. It has also recently been suggested that gravity waves generated by convection may drive the formation of ice clouds in the lower stratosphere and that precipitation of crystals in these clouds may serve as a stratospheric dehydration mechanism.[64]

A quite intriguing article appeared on the USA Today website on January 28th 2010 in the very evening hours, stating that water vapor may flatten the global warming trend.[65]

This statement has first been published in the Science Journal by senior scientist Susan Solomon of the National Oceanic and Atmospheric Administration in Boulder, Colo. Solomon was also a co-chair of one of the groups within the Intergovernmental Panel on Climate Change that put out the definitive forecast of global warming in 2007. The fact that the IPCC got stuck in one of the greatest climate scandals revealed by the Daily telegraph on November 28th 2009, also better known as 'Climate Gate' with huge fraud of climatologic data by Prof. Phil Jones of the University of east Anglia (UEA) over long years[66], does not improve credibility of any panel member.

In this respect it is noteworthy that the UK Information Commissioner's Office that leads

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64 Jensen, E. J., O. B. Toon, L. Pfister, and H. B. Selkirk (1996), Dehydration of the upper troposphere and lower stratosphere by subvisible Cirrus clouds.

65 Doyle R., water vapor may flatten the global warming trend, USA Today with contribution of Associated Press, January 28th 2010.

66 Booker C, Climate change: this is the worst scientific scandal of our generation, Daily Telegraph, November 28th 2009.

the investigation decided that the UEA failed in its duties but said that it could not prosecute those involved because the complaint was made too late.[67] Although it looks that 'Climate Gate' will end in the bin as a result of administrative red tape and carefully planned lobby work, a new leak has already emerged on January 30th 2010 when the Daily Telegraph (again) published that the UN expert panel claims on climate change are based on a student's dissertation and an article in a mountaineering magazine.[68]

At a closer look the claim in Mrs. Solomon's '10/10/10 paper' goes even further: 10% decrease in water vapor at 10 miles above our heads during the last 10 years has slowed down the rate of earth's warming by 25%.[69] The question where the water vapor went to, remains open. But according to this survey it is surprising how big the impact is of such 'small change' (10%!) in water vapor on the surface climate. But according to that survey this isn't an indication that predictions on global warming are overstated: "This doesn't mean there isn't global warming," notes Solomon. "There's no significant debate that it is warmer now than it was 100 years ago, due to anthropogenic (man-made) greenhouse gases."

No one can be surprised that this survey has been ridiculed as a hoax in the aftermath of 'Climate Gate'. However when combining the study material obtained by Jensen in 1996 with the very recent survey by Mrs. Solomon it is obvious that there is a link between the occurrence of natural plus man made Cirrus clouds near the tropopauze, the dehydration of the stratosphere and the flattening of the global warming trend. When this knowledge is linked with the surveys of previous paragraphs it becomes crystal clear that aerosols emitted by aircraft engines have a significant impact on precipitation patterns and surface temperatures.

4.4.2. Other factors affecting climate change:

Although changes in precipitation patterns, surface temperature and stability of the air mass are quite measurable parameters there might be other intangible factors:

One of the most obvious side effects of the formation of contrails is the impact on astronomy. One has seldom a clear sky available for observation in areas with dense air traffic.

With changing cloud cover and subsequent temperature drop in the upper layer of the troposphere, hurricane activity may be increased as a result of the released instability. It is noteworthy that storms and major floods have more than tripled since 1981.[70] No apparent relationship between aircraft engine emissions, aerosols, contrails and hurricane activity has been established yet on a scientifically basis.

It is accepted that knowledge on man made Cirrus cloud is relatively poor and that study of the impact of contrails on the Stratosphere is only in its initial phases. However one can assume that it might have an impact on higher layers and the ozone layer. Ozone depletion does not only occur as a result of industrial activity, but also due to multiple nuclear tests conducted in the 20th century.

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67 Webster B., Scientists in stolen E-mail scandal hid climate data, London Times, January 28th 2010.
68 Gray R. And Lefort R., UN Climate change panel based clims on student dissertation and magazine article, Daily Telegraph, January 30th 2010.
69 Solomon S., ten percent decrease water vapor in the stratosphere slows earth's warming trend, the Science Paper, January 28th 2010.
70 Global Environmental Outlook, GEO4 Environment for Development, United Nations Environmental Programme, 2007.

5. CONTRAILS AND WEATHER MANIPULATION

"If the ionosphere is greatly disturbed, the atmosphere below is subsequently disturbed."

Charles A. Yost, author of "Electrical forces applied to basic weather phenomena", 1992.

5. CONTRAILS AND WEATHER MANIPULATION:

5.1. FROM 'CHEMTRAILS' TO GEO-ENGINEERING:

5.1.1. Scientific basis for a weather manipulation system:

In the previous paragraphs it has been clearly denoted that man made contrails do have a significant and measurable impact on temperature and precipitation on the planet. Especially the data obtained by Professor D. Rosenfeld (see paragraph 4.3.1) proves to be quite solid to sponsor a weather manipulation theory, since altering the aerosol doses in the atmosphere can either increase or decrease precipitation patterns.

This opens a window on a scientific basis in order to produce scenarios to counter global climate change, providing that the designers of that system bear the following considerations in mind:

- Development of a reliable matrix of aerosol ingredients versus field conditions.
- Engineering of a efficient, reliable but low cost system in order to seed the atmosphere.
- Sponsorship through government agencies with a far-reaching commitment of captains of industry.

Actually all elements – except the reliability factor - are in place in order to justify the creation or even the existence of such a system: advanced technology is at hand and financing the system through cap & trade systems ensures nearly unlimited funding. If operated for the benefice of mankind a weather modification could solve many environmental issues, such as reversing desertification and avoid the worst consequences of a global climate change.

However, from a military point of view the organization owning the property rights of such a system also has capability to manipulate temperature and precipitation patterns of other nations, and this at very low cost. Imagine what could happen if such a system falls in the hands of a 'rogue state': it would change global domination patterns. Therefore it is unimaginable that civilians run a weather modification system if it came into existence.

Conspiracy theories flourish nowadays as never before. It is of no surprise that stories of weather manipulation systems, such as 'chemtrails' and HAARP, already have found their way to the Internet. Policy makers write these off as a hoax, because there is no hard scientific evidence for their existence. And if they exist, they are kept secret – which is quite obvious. However it is common knowledge that government policy annex history is manipulated at the discretion of the manipulated state. There are countless examples of this in human history and 'Climate Gate' is without doubt also one of them. All these elements necessitate a closer look to the chemtrail phenomenon, starting from its origin. This is covered in the next paragraph.

This chapter will furthermore not only prove that weather manipulation through contrail formation is not that fictional, but will also produce evidence through patents and research documents that this system is in place and fully operational.

5.1.2. Conspiracy theory character of 'chemtrails':

With the huge explosion of aviation traffic during the last 10 years it was a matter of time before someone would question the ever-increasing amount of contrails. The first reference to production of contrails for specific purposes as described in paragraph 2.4, seems to date from an article by William Thomas dated January 8th, 1999. In that text the suspicious of three people about contrails is recounted. Soon afterwards this man was invited onto a popular radio show at that time (Art Bell), marking the beginning of a real

Internet phenomenon.[71] Apparently it has cross-fertilized itself. A comparison of Internet hits for 'chemtrails' between the years 2004 and 2010 is as follows:[72]

	2004	2010	Change in %
Google	791.000	1.260.000	+59,3%
Blogs	4828	152.000	+3148,3%
Images	9180	170.000	+1851,8%
Videos	2123	47.800	+2251,5%
News	5	22	+440%
Forums	38	110.000	+289.473,7%

This reveals a number of interesting developments:

- Attention by the general public for the 'chemtrail' phenomenon has increased significantly during recent years.
- Images on the Internet with contrails and / or 'chemtrails' have skyrocketed.
- Mainstream news does not hook in on the existence of 'chemtrails'.

The relative strength and importance of the 'chemtrail movement' becomes quite clear when it is compared with other popular topics, such as global warming, UFO's and 'morgellons' (polymers floating in the sky):[73]

Google (total)	2004	2010	CHANGE in %
Tour de France	Unknown	788.000.000	Not applicable
UFO's	36.700.000	36.900.000	+0,5%
Global warming	67.500.000	32.400.000	-52%
'Climate gate'	0	12.100.000	Not applicable
'Chemtrails'	791.000	1.260.000	+59,3%
Morgellons	236.000	249.000	+5,5%

Google (news)	2004	2010	CHANGE in %
Tour de France	Unknown	21.600	Not applicable
Global warming	32.584	23.100	-29,1%
UFO's	929	1890	+203,4%
'Climate gate'	0	401	Not applicable
'Chemtrails'	5	22	+440%
Morgellons	4	9	+225%

71 Contrail science, a brief history of 'chemtrails', www.contrailscience.com
72 Combination of Contrail Science data and own investigation.
73 Idem as footnote 72.

These tables denote clearly that 'chemtrails' are widely regarded by the general public as well as mainstream news agencies as a marginal, dubious phenomenon that is certainly not threatening everyday life and does not need further attention.

In this context it is noteworthy that attention for global warming has fallen dramatically over the last years. It is possibly a result of the ever-increasing controversy of that topic combined with a deep widening economic crisis, necessitating people to keep their feet on the ground. Or perhaps there is just a shift in nomenclature: global cooling, climate change... The sudden appearance of 'climate gate' related stories with high hit rates on the internet might support this theory.

There is more: association with topics that are not backed by hard scientific evidence puts the 'chemtrail phenomenon' automatically in the esoteric or conspiracy theory corner. There are 4 logical reasons for this:

- Because the phenomenon is basically Internet driven, there is no support whatsoever from scientists, political parties or environmental organizations. It is striking that the representative of the ecologist party (Grune) in Vienna even expletively states that the subject is a mere conspiracy theory and there is neither time nor resources available to study the subject.[74]
- Most of the people posting the 'chemtrail' observations on the Internet are not academically qualified to do so. Estimating the cruising altitude of a jet airplane is indeed a tricky affair. Making the difference between contrails and 'chemtrails' is even more challenging. Last but not least posting pictures of grid-pattern contrails on the Internet without a valid caption does not promote any scientific seriousness towards the subject.
- Many websites that provide information about 'chemtrails' also cover other subjects, such as the existence of extra-terrestrial life on earth, global mind control programs and other stuff. As a result of this any story about 'chemtrails' is treated the same way as a hoax and this regardless the value of that information.
- Only a handful Internet sites are dedicated solely on 'chemtrails'. In fact they combine all 'chemtrail' reports within a single state and post it on the Internet. Examples of these are http://arizonaskywatch.com/ and http://www.chemtrails-info.de. These websites often offer test analysis of water samples and reports of spraying actions. Sadly on many occasions the information presented contains scientific errors or wrong interpretations.
- Government instances officially decline in a systematic way the existence of 'chemtrails'. On the other hand all the available information on the Internet does not permit verification of any 'chemtrail' claim. Anonymous reports, such as the testimony of 'Agent Deep Shield' who claimed to be an insider in the 'chemtrail' business'[75], does again not improve credibility.
- Last but not least there are a number of websites that deny the existence of 'chemtrails' in a quite cynical but scientific way. An example of this is http://contrailscience.com/chemtrail-myths/. Its Webmaster, known as 'Unicus', does actually hide his real identity – adding fresh meat for the conspiracy theory grinder that it might be a government agency. However it is significant that this website deals with any of the websites mentioned above, reducing the argumentation of 'chemtrail' protagonists to a piece of rubble.

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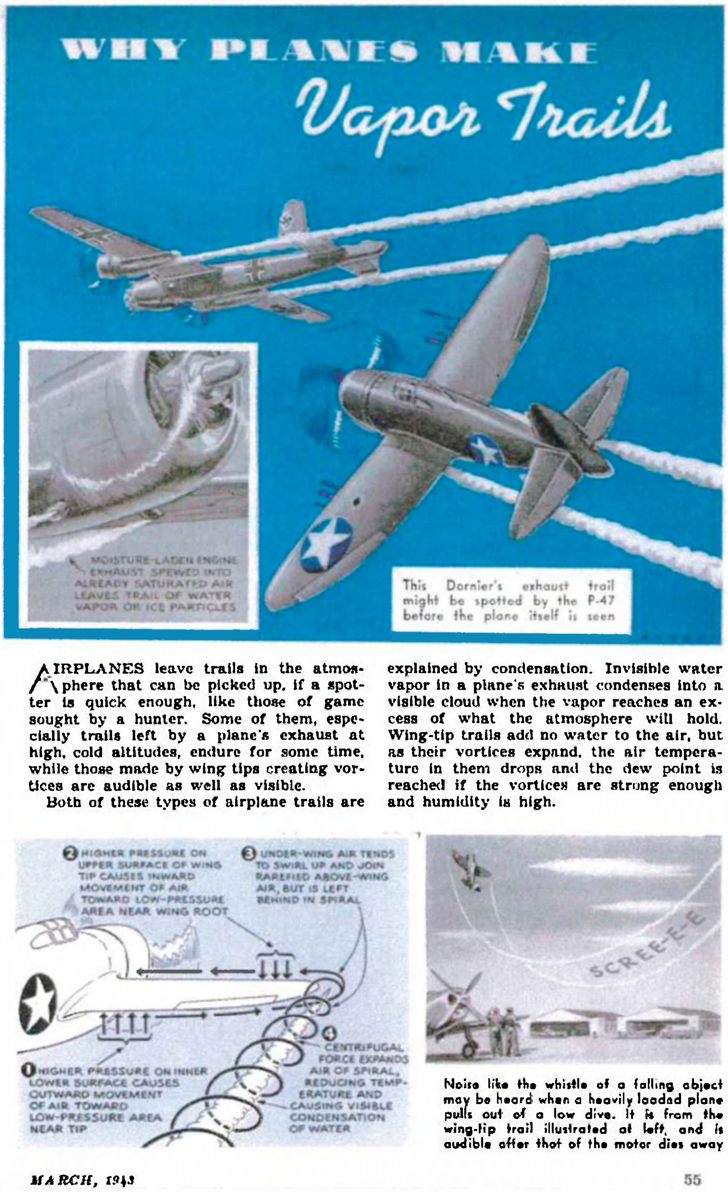
[74] Haderer C and Hies P., Chemtrails, Verschwörung am Himmel?; VF Sammler Verlag 2005, Graz, Austria.
[75] Idem as footnote 74.



WHY PLANES MAKE *Vapor Trails*

This Dornier's exhaust trail might be spotted by the P-47 before the plane itself is seen

AIRPLANES leave trails in the atmosphere that can be picked up, if a spotter is quick enough, like those of game sought by a hunter. Some of them, especially trails left by a plane's exhaust at high, cold altitudes, endure for some time, while those made by wing tips creating vortices are audible as well as visible.

Both of these types of airplane trails are explained by condensation. Invisible water vapor in a plane's exhaust condenses into a visible cloud when the vapor reaches an excess of what the atmosphere will hold. Wing-tip trails add no water to the air, but as their vortices expand, the air temperature in them drops and the dew point is reached if the vortices are strong enough and humidity is high.

Noise like the whistle of a falling object may be heard when a heavily loaded plane pulls out of a low dive. It is from the wing-tip trail illustrated at left, and is audible after that of the motor dies away

MARCH, 1943 55

Home page illustration of the 'contrail science' website. Contrails already exist since the beginning of aviation.[76]

All these elements induce that a scientific approach to 'chemtrails' automatically would compromise researchers and their career. Moreover, who wants to 'chemtrail' the population after all and for what sake? So in the best case the word is badly chosen, because public health is supposed to be one of the backbones of our consumer driven society. Nevertheless it comes as a surprise that some lone authors were able to persuade their editor to publish their book about 'chemtrails' – maybe because it has such a high conspiracy theory level that sells well. Although it is impossible to review all publications, here is a selection of them:

76 www.contrailscience.com, Popular Science, March 1943, Page 55.

AUTHOR	TITLE	COMMENT
Chris Haderer Peter Hiess	Chemtrails, Verschwörung am Himmel?[77]	Rather chaotic book, with a separate chapter about other conspiracy theories. Well documented with ample photographic material, but without any hard scientific evidence. Contains a copy of a letter from a member of the German parliament (Bundestag), in which the limited spraying of barium and aluminum in the atmosphere is acknowledged.
Dr. Leonard G. Horowitz	Death in the air: globalism, terrorism & toxic warfare[78]	The author is a graduate of the Harvard School of Public Health. Chemtrails are linked with jeopardize of public health and CIA's population control projects. Contains many traceable references on bioterrorism.
Jeane Manning Dr. Nick Begich	Angels don't play this HAARP.[79]	Publication solely dedicated to HAARP. Describes the system as an extension of president's Reagan 'star wars project' with the ability to manipulate weather patterns and even produce earthquakes.

5.1.3. Establishment of a reliable research protocol:

Despite some interesting elements in the publications mentioned above and the numerous Internet articles It is quite clear that due to environmental bias it is impossible to analyze 'chemtrails' in a profound and scientific way.

The only option to approach this subject in a serene way is to restart investigation from zero, with new nomenclature and an acceptable research protocol that includes the following:

- History tracking of atmosphere and weather modification programs in Europe, the United States of America, the People Republic of China and Russia / former USSR with new searching tools, such as cloud seeding, geo-engineering and weather force multiplication. The term 'geo-engineering' fits best, because it encompasses all sorts of human intervention to manipulate climate patterns: atmosphere seeding, marine cloud whitening research[80], carbon storage research and even cooling down the earth with a cloud of spaceships (!).[81]
- In-depth study of pending patents covering weather- or atmosphere alteration: patent holder identity, application field, a feasibility study and implementation records.

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77 Haderer C and Hies P., Chemtrails, Verschwörung am Himmel?; VF Sammler Verlag 2005, Graz, Austria, ISBN 3-85365-213-1.
78 Horowitz L.G., d.m.d., m.a., m.p.h., Death in the Air: globalism, terrorism & toxic warfare, Tetrahedron LLC, Sandpoint, U.S.A, 2009, ISBN 978-0-923550-30-1.
79 Manning J., Begich N. Dr., Angels don't play this HAARP: advances in Tesla technology, Earthpulse press, Anchorage, Alaska, U.S.A, second edition, 2007, ISBN 0-9648812-0-9.
80 Copenhagen Consensus Center, press release: top economists recommend climate engineering, September 4th 2009, Copenhagen / Washington.
81 Angel R., Feasibility of cooling down the earth with a cloud of small spacecraft near the inner Lagrange Point (L1), University of Arizona, 17184-17189 PNAS November, 14th 2006, Vol. 103, N°46.

- Analysis of recent scientific and military surveys regarding climate control or climate change mitigation by means of cloud seeding.

- Search through all available channels to obtain actual solid evidence of weather modification programs through reverse engineering: the existence of associations (academic, political, IPCC) that support such programs, order sheets of seeding material on behalf of government agencies and operational charts.

Witness reports, whether anonymous or not, that do not include a valid reference for crosscheck will not be included in the report. Photographic material in the context of this research protocol shall only be released when the probability of error is close to zero.

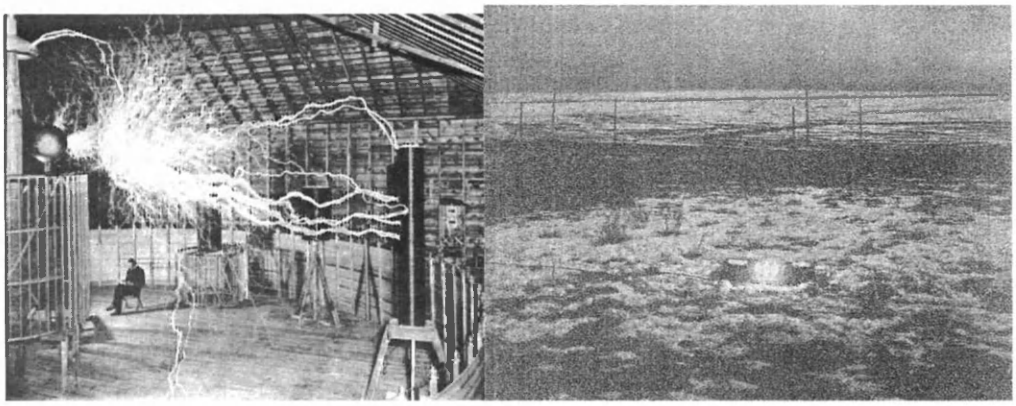
5.2. HISTORY OF GEO-ENGENEERING:

5.2.1. Period 1899-1940: the research work of Nicolas Tesla:

From an agricultural point of view mankind has always wished to intervene in weather patterns to avoid long periods of drought or adverse weather. The first known research in the field of engineering of nature forces is attributed to Nicolas Tesla (1856-1943), a brilliant but still underestimated inventor in established academic circles.

He was one of the most important contributors to the birth of commercial electricity (AC) and is best known for his revolutionary developments in the field of electromagnetism in the late 19th and 20th century. He clashed continuously with Edison's insistence that the United States should stick to his DC-technology for power distribution and electrical lighting – knowing that his system was far more efficient. The fact that only Thomas Edison appears in history records and schoolbooks will become quite obvious.

In 1899 Tesla performed wireless power experiments near Colorado Springs and was able to produce a 30-second golf ball sized lightning.



Left: publicity picture of a participant sitting in Tesla's laboratory in Colorado Springs, circa 1900. Right: actual photo of an experiment in Colorado Springs, during which the bank of light is receiving power from a distant transmitter.[82]

J.P. Morgan, still one of the most important banks on the globe, heavily financed his projects. The majority of the money was spent in the construction of the Warden-Cliff tower, which would be able to create voltages of 15 million Volt and 40-ft lightning-like discharges.[83]

82 Both pictures in public domain.

83 Cheney M., Tesla: man out of time. Simon and Schuster, 2001, ISBN 0743215362.

Actual photograph of the Warden-Cliff tower, prior to its demolition in 1917[84]

However, just as Victor Schauberger was in search of free energy through water vortices[85], Tesla was pursuing electric energy without wires. He patented this invention on April 8th, 1905.[86] Results were satisfactory, but after Tesla admitted to his financiers that an experimental power station on Long Island was to send wireless electrical power as well as messages his public career ended. Although he continued to invent and depose further patents, he was kicked out of the spotlight for the sake of economic interests of J.P. Morgan's shareholders.[87] This is also the reason why Edison was lionized in mainstream history books.

Just before the destruction of the Warden-Cliff tower in 1917, Tesla offered his services for the development of a 'particle beam weapon' to the U.S. department of war and was subsequent kicked out of their office. Persuading people at that time that a magnifying transmitter could beam up electrical energy to the stratosphere and bounce it back to a predetermined place on earth was indeed hopeless, given the level of technology at that time.[88] Nevertheless if this proves to be true Tesla did excite the Schumann cavity (Earth's resonance frequency 7,83 Hz) already in 1899 – 53 years before W.O. Schumann identified it scientifically. He also had a deep insight in the behavior of the ionosphere, more precisely the existence of a skip zone – the extension of a radio signal well beyond the horizon after reflection in the Heaviside layers (invention officially attributed to Tellegen in 1933). A variant of Tesla's idea of the 'magnifying transmitter' has been put in practice in the HAARP-system for study and manipulation of the Aurora Borealis, although its designers repeatedly stress that there is no analogy with Tesla's theories.[89]

Tesla's research work is quite remarkable. In respect of this research one can conclude that he was the first to perform experiments to produce lightning at will and to offer it for both civil and military purposes. Similar projects to trap the enormous reserve of electrical current of a single thunder flash have been undertaken since then, but apparently without success. In Switzerland the test facility burned even down. An Egyptian company, Logic-co in Cairo, is one of the first enterprises that seem to specialize exclusively in the collection of renewable electrical energy from lighting.

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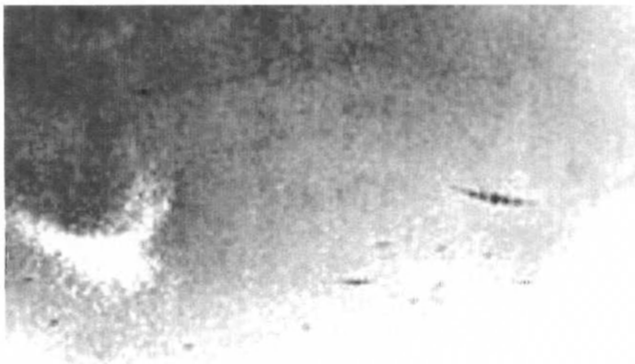
84 By courtesy of the Nikole Tesle Museum, Belgrade, Serbia
85 Schauberger V., das Wesen des Wassers, AT Verlag, München, 2006.
86 US patent 787,412, art of transmitting electrical energy through natural mediums, through U.S. patent office.
87 Idem as footnote 82.
88 Seifer M. Dr., Nikolas Tesla: the history of lasers and particle beam weapons, proceedings of the international Tesla symposium, 1988.
89 http://www.haarp.alaska.edu/haarp/faq.html

5.2.2. Period 1940-1945: first atmospheric seeding:

In both World Wars weather was a considerable and sometimes decisive factor for success or disaster. Parallel to this armies started to rely heavily on camouflage after the stalemate that followed the initial German dash on Paris in 1914. Already less than one year later the German field army developed man-made fog through smokescreens in order to dissimulate troop movements or to go into the offensive through nerve gas attacks, although there are historical references to 'deliberate obscurity' dating back to at least 1565.[90]

The aerial bombing campaigns in World War II, first by the Luftwaffe and followed by very aggressive daylight raids by the 8th Air Force and the Royal Air Force at night marked the first deployment of what later would be known as ECM – Electronic Counter Measures. Although radar was only in its childhood stage during this conflict, it faltered the German 'Blitz' on England. The subsequent struggle between the belligerents was to become known as 'the battle of the beams'. Despite the fact that British intelligence had broken the German Enigma code, they allowed the mass destruction of Coventry by raiders equipped with the 'Knickebein System' in 1941 in order to keep the Germans unaware of this security breach.

In July 1943 the Royal Air Force made one of its most successful sorties by deliberately seeding the atmosphere with masses of small-aluminized paper strips, coded 'Window', to garble German radar. That night Hamburg was flattened with great loss of life. The Luftwaffe operated a similar system in 1944, called Düppel, for disturbing air traffic in the vicinity of allied aerodromes over South East England.[91]



The crescent-shaped white cloud on the left is formed by massively seeding the atmosphere with aluminum particles, thus jamming the German radar and rendering their defense useless, July 1943.[92]

This development is important in the context of this survey, because 'Chaff' as it is called in NATO-nomenclature today is still part of the ECM-defense system and there is evidence that it is tested on a regular basis. On July 19th, 2005 'Düppel' has been used during air exercises over Germany and the Netherlands, causing major disruption on weather radars.[93]

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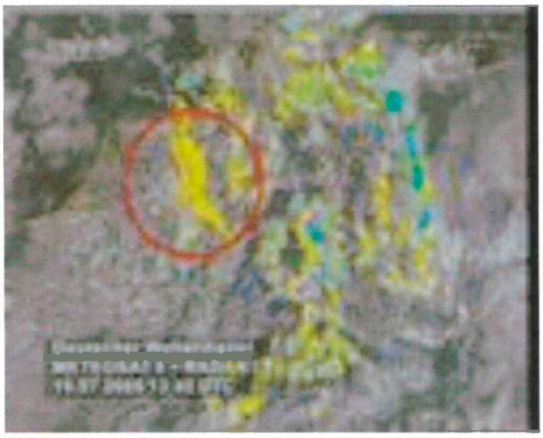
90 The American Heritage® Dictionary of the English Language, Fourth Edition, 2009, Houghton Mifflin Company.

91 The history of radar, BBC maths, science and technology, July, 14th 2003.

92 United Kingdom Government through IWM, public domain.

93 RTL, programm 'Guten Abend', Kartsen Brandt: Bundeswehr manipuliert Wetterkarte, July, 19th 2005.



Hardcopy from the RTL-broadcasting, with the 'Chaff' clearly visible in the area of Kassel. Meteorologists were 'not amused' at that time.

5.2.3. Period 1945-1950: operation Cirrus:

The Second World War ended with the atomic bomb tests, during which uncountable magnetic pulses were released in the atmosphere. As a result of this the U.S. was not only confirmed in its role as world leader, but unlimited funding became available for different projects, including the first weather manipulation programs.

The project, later called Cirrus, originated in 1947 and was led by Nobel laureate Dr. Irving Langmuir and his protégé Dr. Vincent Schaefer in co-operation with the U.S. Army, Navy, Air Force and General Electric. Dr. Schaefer was the man who dropped 1,4 kg of ice pellets on November 13th, 1946 into a super stratus cloud near Schenectady, New York and snow fell. This is the first known fruitful attempt to induce precipitation from a cloud.

To test his theories Schaeffer created a 'cold box' in a laboratory to recreate the same conditions. Breathing into the box produced a tiny cloud of super cooled water droplets, just as in real conditions in the upper part of a cloud. Furthermore Schaeffer discovered that the addition of any substance with a temperature below -40°C would cause million of ice crystals to form in the cloud.[94]

For actual cloud seeding the U.S. Signal Corps became involved in February 1947 and it earned the name Project Cirrus. 37 experimental flights took place in the first half-year that did not always produce the expected results, mainly due to the inherent variability of the weather. Modification of tropical typhoon through dispersion of 80 lbs dry ice in 1947 ended with major flooding in the Savannah area with damage totaling $20 million as a result of a sudden course change.[95] Officially it was classified as an act of God.

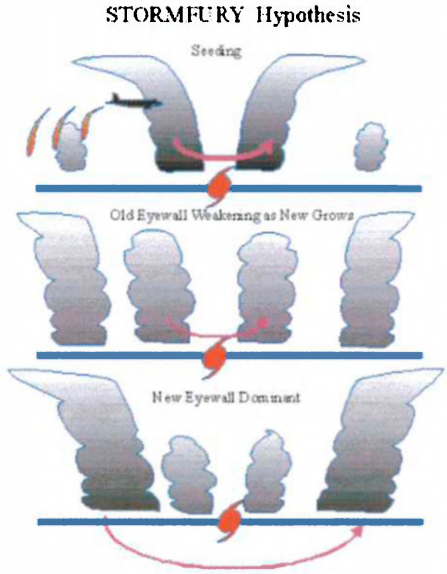
After this the lawyers of General Electric told Dr. Langmuir not to discuss the hurricane case until the statute of limitations ran out for prosecution. Fear for a legal case necessitated further operation out of public eyes and the project was closed in 1950 due to a shift in government with different priorities. In 1958 three nuclear bombs were detonated in the Van Allen radiation belt (protective zone of charged particles trapped in the Earth's magnetic field starting around 2000 miles altitude), starting to deplete the ozone layer with each further attempt by the United States, the former USSR and

[94] Reilly C., Staff Historian, Rain men: scientists here tried to change the weather, Monmouth Message, February 20th 2009, U.S.A.
[95] Idem as footnote 94.

France.[96] This information will be of major importance in the next chapter. Nevertheless project Cirrus is the first confirmed cloud seeding program in history. The full outline of this program can be found in appendix 8.

5.2.4. Start of operation Storm Fury (1962) and Popeye (1967):

Project 'Storm Fury' continued on the knowledge obtained during operation Cirrus, with its main objective to weaken tropical cyclones by flying aircraft into them and seeding with silver iodide.[97] The partners were the U.S. Department of Commerce and the U.S. Navy. The hypothesis was that the silver iodide would cause super cooled water in the storm to freeze and subsequently disrupt the inner structure of the hurricane. Although this hypothesis proved to be incorrect the cloud seeding project continued officially until 1983 with the last experimental flight in 1971.



The hypothesis of operation Storm Fury was incorrect because tropical cyclones seem not to contain that much super cooled water to make cloud seeding effective. Additionally unseeded hurricanes often undergo the same structural changes as the 'treated' ones.[98]

The crew enlisted in Operation 'Stormfury' in 1963. Note the special belly of the Douglas DC6-B on the background for cloud seeding purposes.

[96] National Academy of Sciences, Long time effects of multiple nuclear weapon detonation, 1975, pages 6-7.

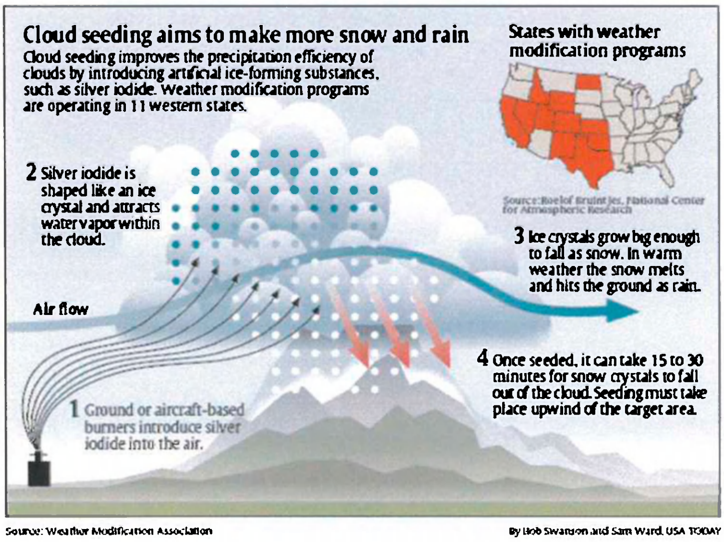
[97] Willoughby, H. E., D. P. Jorgensen, R. A. Black, and S. L. Rosenthal, 1985: Project STORMFURY, A Scientific Chronicle, 1962-1983, *Bull. Amer. Meteor. Soc.*, 66, 505-514.

[98] Atlantic Oceanic and Meteorological Laboratory, Hurricane Research Division, Operation Storm Fury research paper.

In the wake of operation Storm Fury there was also a less known military application during the Vietnam War. From March 1967 until July 1972 the U.S. military cloud seeded 47.409 units of silver iodide to extend the monsoon over North Vietnam and especially in the vicinity of the Ho Chi Min trail. The objectives of this operation, called Popeye, was to deny the enemy the use of roads by softening road surfaces, causing landslides, washing out river crossings and to maintain saturated soil conditions beyond normal time span. It actually resulted in the targeted areas seeing an extension of the monsoon by an average of 30 to 45 days.[99] The full transcription of a U.S. senate hearing about weather modification in S.E. Asia is included in appendix 9.

Operation Popeye proves that weather modification explicitly forms part of the U.S. weapon portfolio ('make mud, not war'), shining new light on the Advisory Committee on Weather Control, which was created in 1953 under direct Federal Government control with Captain H.W. Orville as chairman. Its mission was to study weather-making activities with emphasis on rain making to 'benefit water supplies and land utilization'[100] Despite the mixed results obtained during operation Storm Fury and Popeye it gave way to a very profitable but controversial business with companies offering local weather modification for agricultural purposes through hail cannons and cloud seeding by small aircraft. The successful outcome of such an operation is at least to say doubtful.

Cessna 210 with a device for cloud seeding with silver iodide.



Nowadays there are still several states in the U.S. running cloud seeding programs.

99 Top secret hearing held on March 20, 1974 made public on May 19, 1974 weather modification, SEASIA rain making

100 Substancially increased research programs needed in meteorology to benefit water supplies and land utilization, Journal of Agriculture and Food Chimistry, Page 1192, December 1953.

After the Chernobyl disaster in 1986 major A. Grusin described how the Soviet air force created rain clouds to protect Moscow from radioactive fall out. Sadly the population in Belarus was exposed to radiation doses 20 to 30 times higher than normal, causing intense radiation poisoning in children.[101] The article is included in appendix 10.

Silver iodide is still used on a large scale by the Russian and the Chinese air force for generation of clear skies during military parades or major sports events, such as the Olympic games.[102] In 2009 the mayor of Moscow was planning to spend several million Dollars to pay the Russian Air Force and spray a fine mist of particulate matter (cement dust in 2007, silver iodide or new chemicals) in the clouds. The ideas of operation Cirrus and Storm Fury still stand: seeding the clouds would increase moisture and thus force the clouds to release their precipitation before they reached the capital – 'thus saving the city millions in snow removal costs'.[103]

Preliminary tests revealed strange hole punched clouds over Moscow that worried its inhabitants.

This strange cloud over Moscow in November 2009 is attributed to a cloud seeding test.

Unfortunately the 'experiment' proved to be a huge failure with 417.000 cubic meters snow shoveled between February 21st and 22nd 2010 – breaking the record of 1966.[104] It has not been determined if there is any correlation between the harsh winter conditions in Moscow or the rest of Europe in this period and any cloud seeding initiatives.

However, it is clear that extensive hard evidence exists of weather manipulation for both civil and military purposes on micro- and macro scale since the Eisenhower administration, with ever changing seeding material ranging from dry ice over silver iodide to cement and particulate matter. However one must bear in mind that mechanical cloud seeding is quite expensive and it was a matter of time before alternative and more efficient ways of manipulation of the atmosphere were to be developed.

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101 Gray R., How we made the Chernobyl rain, Daily telegraph, April 22nd 2007.
102 Michaels J., China may attempt to alter weather for Olympics, Meteorology news, July 15th, 2008.
103 Michaels J., Moscow testing cloud seeding; promises winter without snow, Meteorology News, October, 19th 2009.
104 Moskou onder een dik pak sneeuw, De telegraaf, 22 Februari 2010.

5.2.5. U.S. and Soviet 'proof of concept' ELF-projects (1975 to 1995):

A 'proof of concept' project is one where advanced research experiments are designed to test, usually on a smaller scale, specific applications of research. These tests allow researchers to extrapolate results, which can be used to engineer full size technology systems. Within the scope of this survey a 'proof of concept' project for weather modification is the last step before full weapon system development (military applications) or geo-engineering around the planet (civil and military applications).

After the American debacle in Vietnam the two opposing blocks shifted to a more silent cold war and this despite extensive strategic arms limitations talks (SALT). Instead of dropping masses of silver iodide in the atmosphere and battering the troposphere with atomic tests –already totaling 400 kilotons at that time - a subtle battle of the frequencies between U.S. and opposing Soviet forces made its headway. Its ultimate target: replacing thermonuclear weapons by 'non lethal' electro pulses through manipulation of the ionosphere and the magnetosphere.[105]

Development of such devices started quite a long time ago. Already in 1966 Anthony Ferraro at the Penn State University performed the first military funded experiments with a 500kW ionosphere heater.[106] A high-power transmitter would heat a region of the lower ionosphere while a weaker transmitter was pulsing. Thus the experimenters could study wave interaction within that specific layer of earth's atmosphere. They had to shut down the project some years later because there was an unacceptable interference with air traffic control and other types of radio communication. As a result of this, military decision makers decided that all future projects would be located in remote places on the globe.

In 1974 Dr. R. Helliwell and J. Katsufrakis of the Stanford University's Radio Science Laboratory showed that a very low frequency radio wave (VLF) could vibrate the magnetosphere[107] (The region above the ionosphere in which the magnetic field of the earth has a dominant control over the motions of gas and fast charged particles), thus confirming the research work of Anthony Ferraro.

Exact one year later in 1975 the U.S. Navy launched an ELF-facility (Extreme Low Frequency) capable to radio-contact deep running Polaris or Poseidon ICBM missile carrying submarines in case of extreme national disaster. This operation, with code name Project Sanguine, consisted of the development of a communication network in the 45 to 75 Hz frequency range plus a grid of deeply buried cables covering 1250 square miles. In this system, sited in specially selected rock and ground formations, the earth acts as a conductor, with the rock formations forcing the radio waves outward into the ionosphere instead of inward toward the earth's core.[108] The saturation of the ionosphere forces some of these ELF signals underwater to a considerable depth, enabling submerged submarines to receive and react to messages from a distance of over 2500 miles even if normal communication channels should be destroyed in a preemptive attack. A similar system, called ZEVS with its transmitter located near Murmansk, is still in use in Russian Navy.[109]

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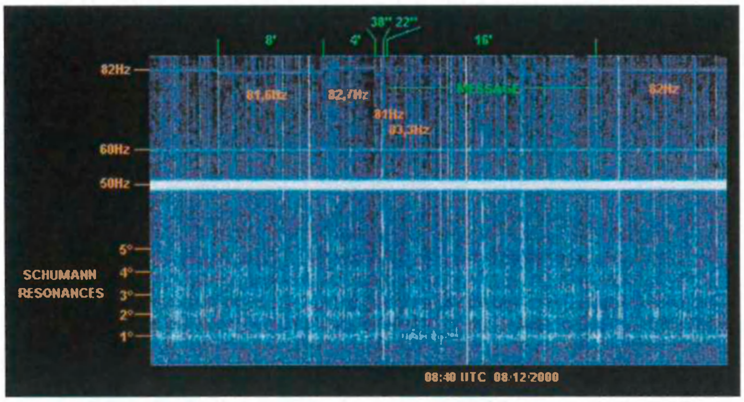
105 U.S. patent 4,686, 605 – issued August 11th 1987 to Bernard J. Eastlund and assigned to APTI inc., Method and appartus for altering a region in the Earth's atmosphere, Ionosphere and/or Magnetosphere.
106 Ferraro A.J., Reflections on 40+ years of ionospheric research, Communication & Space Science Laboratory, Penn State University, United States
107 Stanford University VLF group website http://www.star.stanford.edu/people/rah.html
108 Wallechinsky D. And Wallace I., Major engineering events in history: Project Sanguine nears operation, 1981.
109 Jacobsen T., ZEVS, the Russian 82 Hz ELF transmitter, Norway.



A ZEVS transmission recorded in Italia by Renato Romero on the 8th of December 2000, at 08:40 UTC. The "message waiting" signal, 81.6 Hz low for 8 minutes, 82.7 Hz high for 4 minutes is easily detected in the spectrogram. After the 16 minutes long message sequence of the transmission is again the carrier at 82 Hz. Because of the long exposure are the Schumann resonance bands easily visible at the bottom of the spectrogram.

However in the field of ELF-transmitters the Soviets proved to be far superior to the Americans at that date with significant amount of manpower and resources attributed for the development of a fully operational ionospheric heater in Zelanogradskaya near Moscow, which was completed in 1981. There are reports that the device was not only used for ionosphere study and modeling, but also for pulsing of ELF-waves on a 10 Hz frequency in the form of a 'woodpecker signal' –just above the natural Schumann resonance frequency of the earth of 7.83 Hz - in order to disturb communication and to resonate with neurons of human brains at key brainwave rhythms.[110] The existence of a U.S. radio frequency radiometry handbook, which contains mathematics for calculation of the dosages of radio frequency radiation necessary to cause changes in animals and humans, is a silent witness of the battle of the frequencies between the United States and the former Soviet Union.[111] After the collapse of the U.S.S.R. many projects were abandoned and the Americans took the lead in the research. Today 10 known Ionosphere heaters or research facilities are operative around the globe (4 U.S. staffed, 1 in Norway operated by the German Max Planck Institute since 1991 and 5 Russian).

This 'ionosphere study station' at Zmiev, currently in the Ukraine, has been abandoned after the demise of the Soviet Union.[112]

110 Dr. Begich J & Manning J., Angels don't play this HAARP, advances in Tesla technology, page 17, Earthpulse press, Anchorage, ninth printing, 2007.

111 Radio frequency radiation dosimetry handbook, U.S. Air Force School of Aerospace medicine, Brooks Air Force Base, October 1986.

112 Picture by courtesy of the Pravda, http://english.pravda.ru/ img/idb/photo/5-67.jpg

The study of ELF-transmitters either for civil or military purposes is particular important in the scope of this survey, because alteration or manipulation of the ionosphere at a specific place inevitably alters the weather below. When transmitting in the VLF or ELF frequency range the ionosphere is sliced about in the same way of a space shuttle entering or leaving the atmosphere, leaving an incision at the point of impact. Due to the nature of propagation of VLF and ELF-waves these signals cause streams of particles to rain down beyond the horizon far from the transmitter and in the outermost regions of the atmosphere with very little loss of signal, altering the motion of free electrons and causing electronic rain that influence weather patterns.[113] This opens a window towards peaceful applications but also military endeavors, as been demonstrated during the Vietnam conflict with operation Popeye.

In that respect it is worth to mention that the U.S. Air Force, the U.S. Navy and the Defense Advanced Research Projects Agency, together with an array of civil partners, have established HAARP in 1995 (test runs), the High Frequency Active Auroral Research Program. While the military provide technical expertise, management, administration and evaluation of the program its civil partners are partly responsible for the funding. According to official sources HAARP is a scientific endeavor aimed at studying the properties and behavior of the ionosphere by means of high power HF-transmitters aiming to manipulate the Aurora Borealis (Northern light), with particular emphasis on being able to understand and use it to enhance communications and surveillance systems for both civilian and defense purposes.[114]

The HAARP-antenna array at Anchorage, Alaska[115]

The main differences between the Russian or European stations and HAARP are as follows:

- When fully operational somewhere beyond 2010 the HAARP team will operate an ionosphere heater with an effective ERP well above 1 Giga Watt, in short the most powerful facility in the world.[116] That would actually allow a concentration of one Watt per cubic centimeter, where its Russian counterparts are only able to deliver a millionth of one Watt.[117]

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113 VLF, getting particles excited, Science News, Society for science and the Public, December 1982, P.392.
114 Official HAARP website, http://www.haarp.alaska.edu/haarp/factSheet.html
115 HAARP Cam, recorded on February, 7th 2010, official HAARP website.
116 HAARP, Joint Program Plans and Activities, Air Force Geophysics Laboratory, Navy Office of Naval Research, February 1990.
117 Amendment January 1987 to the original patent application of Bernard Eastlund for the subsequently issued U.S. patent number 4,686,605.

- Due to its high concentration of power HAARP can stab the ionosphere with a more focused beam, while the others spread it over an increasingly large area as the energy moves away from the transmitter.
- The safety limits for VLF-and ELF-waves in the HAARP final environmental impact statement were set a 1000 times higher than the level considered safe in the former Soviet Union.[118]

As a result of these developments in Alaska deputies held a heated discussion about HAARP in the Russian parliament, the Duma, in the year 2002. They even drew up an appeal to the President Putin and the UN. They demanded to set up an international commission for the investigation of the experiments conducted in Alaska, which has cynically been waved by the U.S. authorities, as HAARP is a 'pure scientific project'.[119]

Nevertheless, bearing in mind the outcome of project Sanguine and when looking closer at the mission statement of HAARP it is obvious that the system is more than a scientific project with possible leads for the D.O.D. (U.S. Department of Defense). It is actually a full-blown operational platform that greatly improves the performance of the U.S. military C3 system (Communications, Control and Command), combining all existing weapon systems in one device and making all other friendly or enemy systems obsolete.[120] In the 'National Defense Authorization Act for fiscal year 1995' it is even stated that the transmitter in Alaska, besides providing a world class research facility for ionospheric studies, could allow earth-penetrating tomography over de northern hemisphere, permitting the detection and exact location of tunnels and shelters.[121]

However, during communication with the public U.S. official sources have always denied that HAARP is a military system and on their official website nothing points in this direction. Moreover the military firmly contest that there is any link between HAARP and patent 4,686,605, a theory that is brought forward by Jean Manning and Dr. Nick Begich.[122] This patent, which has been deposed by Bernard J. Eastlund on behalf of APTI Inc. (ARCO Power Technologies Inc.), contains 15 claims, ranging from a method to alter at least one region above the earth's surface with electromagnetic radiation over methods of providing artificial particles in the atmosphere excitation of electron cyclotron resonance.[123] If such a device would exist man made earthquakes would be within reach by manipulating the Schumann frequency through resonance.

By the matter of fact many bits and pieces of evidence do link the N°4,686,605 patent. First of all APTI, a small company holding an array of patents relating to weather modification and the initial HAARP contractor, was bought out to E-systems in June 1994[124] only to be bought out again in April 1995 by Raytheon Corporation – one of the main suppliers and biggest contractors in the U.S. Aerospace and defense industry.[125] A fact not to neglect is that Raytheon was also an initial and losing bidder for the HAARP project and the buy out some years later rewarded them instantly with the Eastlund technology plus the contract.[126] So it is pointless to argument that HAARP is civil

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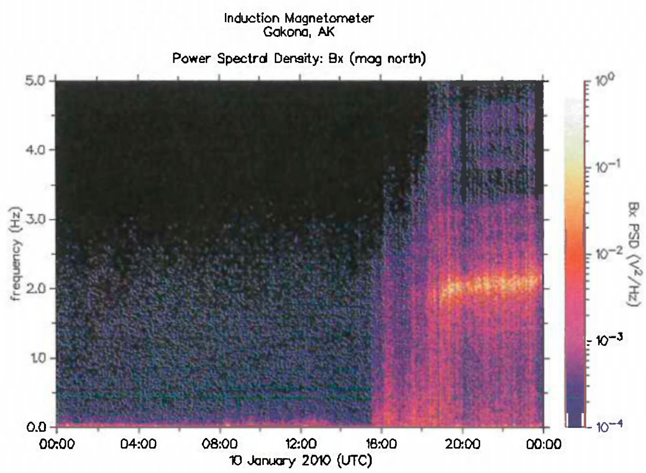
118 Lt. Col. David J. Dean USAF, Low Intensity Conflict and Modern Technology, Air University Press, Center for Aerospace doctrine, Research and Education, Maxwell Air Force Base, June 1986.
119 USA and Russia supposedly develop secret meteorological weapons, Pravda, English Edition, September 30th 2005.
120 Idem as footnote 118.
121 National Defense Authorization Act for fiscal year 1995, 103rd congress, 2nd session, Report 103-82, Calendar 459, Report to accompany S.2182, Committee on Armed Services United States Senate, June 14th 1994.
122 Dr. Begich J & Manning J., Angels don't play this HAARP, advances in Tesla technology, page 17, Earthpulse press, Anchorage, ninth printing, 2007.
123 U.S. patent 4,686, 605 – issued August 11th 1987 to Bernard J. Eastlund and assigned to APTI inc., Method and appartus for altering a region in the Earth's atmosphere, Ionosphere and/or Magnetosphere, claims 1, 2 and 11.
124 The New York Times, E-Systems buys ARCO Power Technologies", June 30th, 1994.
125 The Wall Street Journal, Raytheon to acquire E-systems for $64 a share, Page 1, April 3rd 1995.
126 Idem as footnote 122.

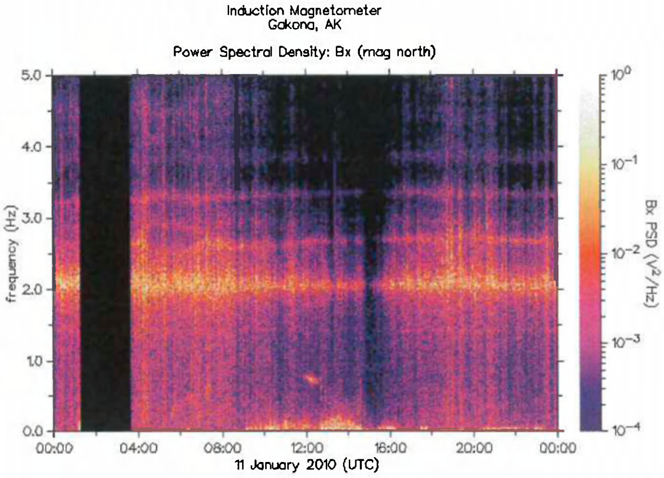
technology: it is about the same as telling that the facility that engineered the first atomic bomb in1945 was a pure scientific and peaceful project. Secondly a U.S. Air Force document that unexpectedly emerged in a public library explicitly states that it is the intention to have HAARP transmitting at 100 billions of Watts effective energy and that 'we have never seen anything like this on earth'.[127] Last but not least claim 15 of the N°4,686,605 patent describes a method of generation of electromagnetic radiation within the magnetic latitudes that encompass Alaska, exactly the same place where the HAARP facility is built. This last bit closes the loop between APTI, Raytheon and the real purpose of HAARP. The full description of patent 4,686,605 is included in appendix 11.

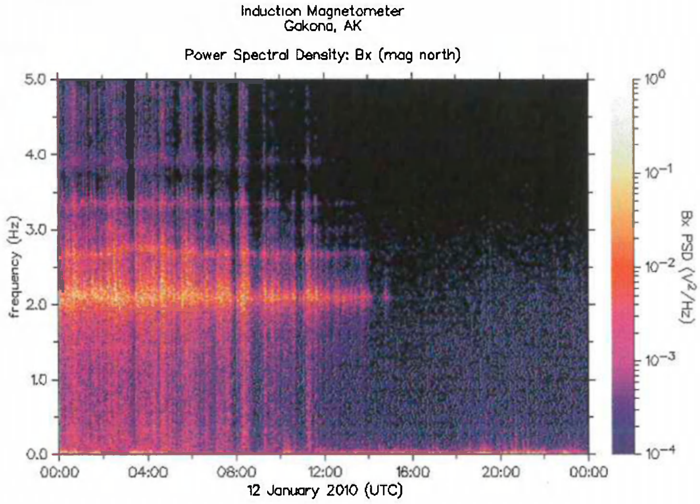
Of course HAARP does also open a window towards civil applications, such as replenishing of ozone holes and binding of excess CO_2 in the lower atmosphere as part of a solution for global climate change but also 'for owning the weather' and remodeling the ionosphere because the current layer is too unstable for the outcome of strategic military operations. This point of view is clearly underwritten by the Russian environmental monitor Valery Stasenko who states that HAARP is a very serious issue and that perturbations in the magnetosphere and ionosphere can really impact climate, even on a global scale.[128] Refer to appendix 12 for the full article from the Russian Pravda.

As explained at the beginning of this paragraph the 'war of the frequencies' between the Americans and the Russians continued well beyond the cold war and well into the 21st century. In 2005 the American meteorologist Scott Stevens accused Russian military specialists for the destruction of New Orleans by hurricane Katrina, although it is questionable if even high power devices as HAARP are capable to unleash such power. However, what to think about the out print of the HAARP induction magnetometer, which detects temporal variation of the geomagnetic field (flux), for the period between 10 and 12 January 2010? On Tuesday January 12th at 16.53 local time (21.53 UTC) Haiti was devastated by an Earth Quake. The official readings of the magnetometer were as follows:[129]



[127] A U.S. Air Force document, *Technical Memorandum #195,presentations from the HAARP workshop on ionospheric heating diagnostics,* issued October 1991, page 185, Phillips Laboratory, Hanscom AFB.
[128] USA and Russia supposedly develop secret meteorological weapons, Pravda, English Edition, September 30th 2005.
[129] http://maestro.haarp.alaska.edu/cgi-bin/scmag/disp-scmag.cgi





Variations in magnetic flux were extreme during the 24-hours preceding the earthquake, acting as a precursor of what was going to happen somewhere around the globe in the next hours. It is unknown if the U.S. military were fully proficient in decoding this information at that time in order to initiate an evacuation, whether information has deliberately been held for national interests or even worse.

Whatsoever American, Russian or European official sources state it is crystal clear that weather modification at the beginning of the 21st century is not a hoax nor a 'conspiracy theory' but an iron truth. It is undeniable that the United States is on top of research in this field and is deliberately withholding vital information on weather modification and possible infringement of international laws of sovereignty, not only to allied or neutral states but also towards their own citizens.

5.2.6. the year 1996 - Weather as a force multiplier: owning the weather in 2025:

The title of this paragraph is also the title of a research paper, presented by Col Tamzy J. House and his team to the U.S. Air Force on June 17th 1996. It forms part of a group of studies labeled '2025', designed to comply with a directive from the chief of Staff of the Air Force to examine the "concepts, capabilities and technologies the United States will require to remain the dominant air and space force in future".[130] As one might think it is not an isolated publication by some eager and combative military. On the contrary there are many more projects in this area of interest, such as the research paper 'Alternate futures for 2025: security planning to avoid surprises' that even introduces the concept of a global "Pax Americana".[131] When looking closer at the individual research papers the only relevant conclusion is that extensive human resources are allocated to U.S. strategic planning and all research papers are closely interconnected and fit into a global goal.

The research document 'owning the weather in 2025', combines all the previously obtained knowledge in the field of weather control and possible developments into the following operational capabilities matrix:[132]

DEGRADE ENEMY FORCES	ENHANCE FRIENDLY FORCES
Precipitation enhancement Flooding of lines of communication Reduce recce effectiveness Decrease comfort level / morale	**Precipitation avoidance** Maintain / improve lines of communication Maintain visibility Maintain comfort / morale
Storm enhancement Deny operations	**Storm modification** Choose battle space environment
Precipitation Denial Deny fresh water / inducing drought	**Fog and cloud generation** Increase concealment
Space weather Disrupt Communications / radar Disable / destroy space assets	**Space weather** Improve communication reliability Intercept enemy transmissions Revitalize space assets
Fog and cloud removal Deny concealment Increase vulnerability to recce	**Fog and cloud removal** Maintain airfield operations Enhance recce effectiveness
Detect hostile weather activities	**Defend against enemy capabilities**

This matrix is of particular interest, because it does not only include known weather manipulation instruments such as cloud seeding through silver iodide as used in the Vietnam conflict and modeling of the ionosphere through HAARP ('space weather'), but also precipitation and storm control by means of cloud or contrail generation. This option will be discussed in the next chapter.

130 Col T.M. House and team, Weather as a force multiplier, a research paper presented to Air Force 2025, page ii, Department of Defense School, August 1996.
131 Col J.A. Engelbrecht, Jr., PhD and team, a research paper presented to Air Force 2025, page 107, Department of Defense School, April 1996.
132 Refer to footnote 130, page vii.

This research document is very clear and provides even the most skeptic climatologist who denies global weather manipulation by the U.S. and its allies an insight in what to expect in the 21st century: 'Current demographic, economic and environmental trends will create global stresses that provide the impetus necessary for many countries or groups to turn weather modification ability into capability. In the United States weather modification will likely become part of national security policy with both domestic and international applications. Our government will pursue such a policy, depending on its interests, at various levels.'[133] The research paper does however not specify if current environmental and economic crises are deliberately triggered or created in order to achieve the goals as set in the directive of the U.S. Chief of Staff.

The authors of the research papers explicitly admit that the U.S. forces possess a high capability for fog and cloud modification as well as an average capability for space weather modification, which reflects the fact that HAARP is not operating at full capacity.[134] In that respect they have established a core competence road map in order to obtain overall artificial weather control in the year 2025. As water sources become scarcer 'in volatile parts of the world' the importance of precipitation modification for economic as well as defense purposes is likely to increase.[135] It is a fact that water will become the most valuable commodity in the next decades and control of existing water supplies automatically generates the next world power.

On top of this the research paper also includes a system development road map to weather modification in 2025 with a very precise time line. It includes the following applications:[136]

- Introduction of artificial ionospheric mirrors around the year 2000 with a very sharp upraise of such operations as from 2008. One can extrapolate that the HAARP system will be fully operational after 2015.
- Use of chemicals for atmospheric seeding as from the year 2000 in order to obtain Weather Force Support in 2015 and fully controllable virtual weather by 2025. The aerospace delivery vehicles' graphic and the graph for the use of chemicals are identical, which indicates a huge increase of spraying actions. It is clear that the sum of all U.S. and NATO military assets are not sufficient to achieve the desired targets and civil aviation has to be included in order to achieve success.
- Introduction of smart clouds through nanotechnology around the year 2004 with an exponential increase of this application after 2010. The same applies to the use of 'directed energy' – a euphemism for ionospheric heating.
- A very curious application is the introduction of 'Carbon Black Dust' (CBD) as from the year 2005 – a technology that has to be developed by the DOD according to the document.

Although this unclassified research paper contains a disclaimer that it is a fictional representation of future scenarios and the viewpoints do not reflect the official policy of the U.S. Air Force, DOD or U.S. government its mere existence highlights the ambition of the military in the field of weather control. As has been adequately illustrated the technology for weather manipulation is already in place and the allocation of human resources to such projects is only possible after prior permission by the DOD, the intelligence services such as the NSA and finally senior decision makers in the U.S. government itself.

Last but not least there exists also a civil counterpart of the '2025 project', which is called the Weather Modification Association (WMA). This organization also publishes annually or more frequently the journal of weather modification. Its mission goals is to enable

133 Idem as footnote 130
134 Idem as footnote 130, page 32
135 Idem as footnote 130, page 34
136 Idem as footnote 130

persons, political entities and other organizations to make informed decisions about the application of weather modification technologies, to provide adequate water supplies and to reduce natural weather hazards.[137] Although designed for beneficial use the mission statement has a strong resemblance with the operational capabilities matrix on the 'enhance friendly forces' side of the military '2025' project.

An excerpt of the research paper, which includes the front page, the disclaimer, the table of contents and the different graphics, is included in appendix 13.

5.2.7. The bare necessity of geo-engineering through cloud generation for survival of the planet (1996 – 2010):

In the first decade of the 21st century a new development took place on planet Earth: climate is gradually changing and whole eco systems are endangered as a result of human activity. The former secretary-general of the United Nations, Koffi Annan, put it crystal clear in the introduction section of the impressive GEO4-document released by the IPCC in 2007: 'Imagine a world in which environmental change threatens people's health, physical security, material needs and social cohesion. This is a world beset by increasingly intense and frequent storms, and by rising sea levels. Some people experience extensive flooding, while others endure intense droughts. Species extension occurs at rates never before witnessed. Safe water is increasingly limited, hindering economic activity. Land degradation endangers the lives of millions of people. This is the world today.'[138] In a short period of time 'global warming' came on top of many political agendas.

Between 2003 and the outbreak of the credit crunch in 2008 'global warming', dwindling natural resources and the safeguard of the planet in general proved to be a very popular media topic, partly as a result of the release of the movie 'an inconvenient truth' by Al Gore – who would later become the first billionaire in cap & trade.

Although 'global warming' remains a very controversial subject after the eruption of 'climate gate' in 2009 and 'climate change' would be a much more appropriate description of this phenomenon P.M. Della-Marta and his team of Meteoswiss proved through an analysis of 54 homogenised daily maximum temperature series in 15 European countries

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137 Weather Modification Association website, http://weathermodification.org/organisation.htm
138 GEO4, United Nations Environment Program, Introduction section, 2007.

that summer heat waves have doubled since 1880, both in number of hot days as the length of the heat waves.[139] His research work confirms data obtained in earlier research papers, such as the Press Therm Climate document, prepared on presidential order after the extreme heat wave of 2003 in France that resulted in 14,947 excess causalities of whom 2200 people died in one single day - August 12th 2003.[140] Even when putting the effects of 'climate gate' into account one can logically assume that our quality of life is in great danger and immediate action is needed to safeguard the planet.

A lot of mitigation scenarios were developed to counter 'global warming', such as restriction of the various greenhouse gasses through regulation and the creation of the profitable cap & trade business, making pollution one of the business fields with the highest return on investment. As from 2001 more exotic scenarios were introduced in the IPCC assessment reports such as iron fertilization in oceans, chemical buffering and 'geo engineering' – large size and deliberately manipulation of Earth environment through its energy balance and reflection of additional incoming solar radiation back into space.[141]

However geo-engineering scenarios for reduction of global warming on a large scale already appear in much older documents, such as U.S. patent 5,003,186 of March 26th 1991, held by Hughes Aircraft Company. It contains 18 claims to reduce global warming through stratospheric seeding with Aluminum Oxide (claim 3 and 12), Thorium Oxide (claim 4 and 13) and refractory Welsbach material for reflection of incoming solar radiation (claims 7 and 10) with a particle size of 10 to 100 Microns (claims 6 and 16) and dispersed at altitudes between 7 to 13 kilometers (claims 5 and 14).[142] Refer to appendix 14 for the full outline of patent 5,003,186.

So far government sources systematically deny the existence of operational atmospheric spraying schemes in order to cut 'global warming', but one must bear in mind that the proposed scenario by the IPCC in 2001 is identical to the claims contained in the Welsbach patent. Moreover Hughes Aircraft Company has been acquired by Raytheon in 1997, which is exact the same company that acquired E-systems and the HAARP contract.[143]

The exact method of spraying of the mix that comprises one of more of the oxides of metals (claims 1 and 11) is not firmly specified in patent 5,003,186, although one possible method of delivery is briefly described in the section 'background of the invention': 'one proposed solution to the problem of global warming involves the seeding of the atmosphere with metallic particles. <u>One technique proposed to seed the metallic particles was to add the tiny particles to the fuel of jet airlines, so that the tiny particles would be emitted from the jet engine while the airline was as it cruising altitude.</u> While this method would increase the reflection of visible light incident from space, the metallic particles would trap the long wavelength blackbody radiation released from the earth. This could result in the net increase in global warming. It is therefore an object of the present invention to provide a method for reduction in global warming due to the greenhouse effect which permits heat to escape through the atmosphere.'[144]

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139 Doubled length of Western European Summer Heat Waves since 1880, Della-Marta, P.M., M. R. Haylock, J. Lutherbach, and H. Wanner 2007, Journal of Geophysical research, volume 112, D15103, doi:10.1029/2007JD008510 – published August, 3rd 2007, Federal Office of Meteorology and Climatology Meteoswiss, Zürich

140 Press Therm Climat,142:25-30. Data for Dijon-Longvic Airbase, Centre Météorologique Départemental de la Côte d'Or, Dijon, 2005.

141 IPCC Third Assessment Report, Climate Change 2001, working group III: mitigation, section 4.7 Biological uptake in oceans and freshwater reservoirs, and geo-engineering, GRID-Arendal, 2003.

142 U.S. patent 5,003,186, Stratospheric Welsbach seeding for reduction of global warming, March 26th 1991.

143 Raytheon Company and Hughes Electronic Defense Business (Hughes Aircraft) to merge, creating $21 billion enterprise – combination creates a world leader in defense electronics, Raytheon press release, Raytheon Company Corporate Communication, New York, January 16th, 1997

144 Idem as footnote 142, page 1.

However a recent research paper by David L. Mitchell and William Finnegan dated October 30th 2009 shines a new light on atmospheric seeding by aircraft, with two possible methods of delivery:[145]

- The seeding material, comprised of a pressed composite of reagent Bismuth metal, Aluminum and Gilsonite (natural Hydrocarbon) could be either dissolved or suspended in the jet fuel of commercial airliners and later burned with the fuel to create seeding aerosol.
- Alternatively the mix could be directly injected into the hot engine exhaust, which should vaporize the seeding material, allowing it to condense as aerosol in the jet contrail. In this respect it is noteworthy that the Secretary of the U.S. navy is in possession of patent 3,899,144, dated August 12th 1975, claiming the invention of specific contrail generation apparatus for producing a powder contrail having maximum radiation scattering ability for a given weight material.[146] The seeding material in this document again consists of 85% metallic particles and 15% colloidal Silica and Silica gel in order to produce a stable contrail that has a residence period of 1 up to 2 weeks as the Mitchell and Finnegan survey claims.[147] Refer to appendix 15 for the full text of patent 3,899,144.

As discussed in the case study in paragraph 3.3.2 the KC135 and possible the AWACS aircraft are already equipped with pods to enable spraying operations. The question arises if the higher gas emission ratios than those in civil aviation are not part of this type of delivery mechanism for geo-engineering.

Thus basically the first method with direct injection through jet fuel is primarily designed for civil aviation, since delivery of the mixture through pods would involve direct co-operation of airline staff, management, crews, maintenance personnel and generally attract media attention. This is also the basic argument that is being used by websites that deny the existence of 'chemtrails', such as 'contrail science'.[148] This is very true, since the very nature of such an operation would involve intense co-operation at all levels. However, the Dutch Airport Portal website, supposed to be a platform for professional pilots, contains a lot of postings referring to spraying schemes with product 'X-432' (a Barium derivate).[149] It contains even excerpts from a company's operating manual and suggestions that KLM, the national Dutch carrier, is a partner in the spraying program. Some consider this portal as a hoax, but one can only wonder why so much energy is used to generate such 'rubbish' that has 'no purpose'. Furthermore the nomenclature is similar to standard operating procedures (SOP) and airplane checklists as used in commercial aviation. Refer to appendix 16 for a printout of some of the postings on this website.

In addition evidence has shown up that confirms the fact that European ministries of defense have bought great amounts of Barium or Barytine C14. The concrete documents (appendix 17) have been removed from this ~~document~~ report for security reasons and kept in a safe place.

PV

10/05/2010

[illegible] [150] Taking into account that Barytine C14 is used as a tracer for measurement of sea currents as part of global climate modeling[151] it

145 Michell D.L. & Finnegan W., Modification of Cirrus clouds to reduce global warming, Desert Research Institute, Reno, USA, October 30th 2009.

146 U.S. patent 3,899,144, Powder Contrail Generation, August 12th 1975.

147 Idem as footnote 145.

148 Contrail science, chemtrail plausibility study, http://contrailscience.com/chemtrail-plausibility-study/

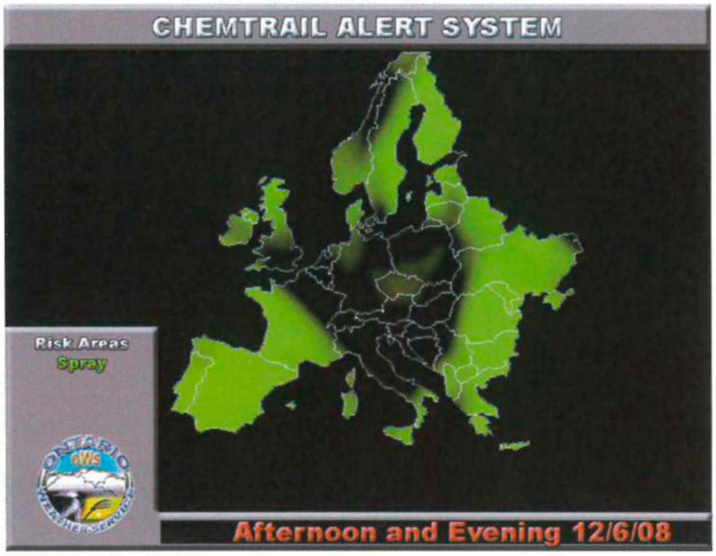
149 http://www.airwork.nl/bulletinboard/showthread.php?t=6001&page=3

150

151 Modelisation Climatique Globale, PNEDC, page 60, Institut National des Sciences de l'Univers, Centre National de la Recherche Scientifique. 2005.

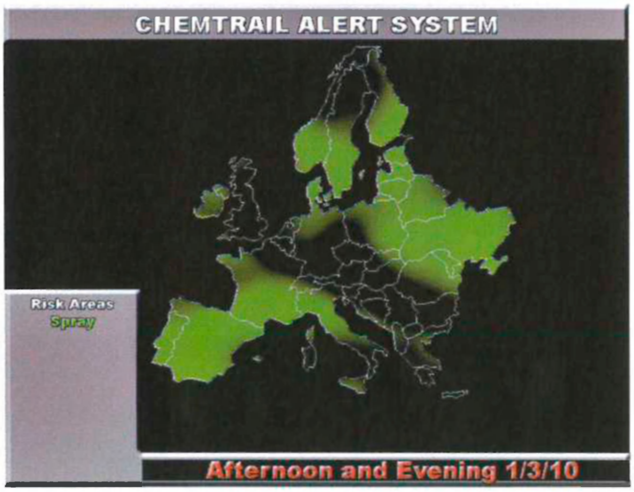
comes at no surprise why such large quantities are ordered. Refer to appendix 17 for different screenshots of the order confirmation.

On top of this comes a map with spraying schemes in Europe, which has been released by Kevin Martin, a meteorologist working for the Ontario Weather Service in 2008. Later on such maps displaying intended spraying schemes for Europe, Australia and the United States appeared on the Southern California Authority website. Currently this section of the website has been shut down since January 6th 2010 for unknown reasons.

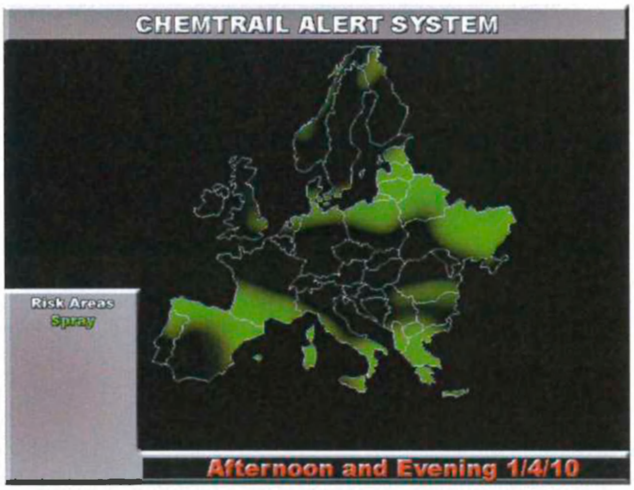


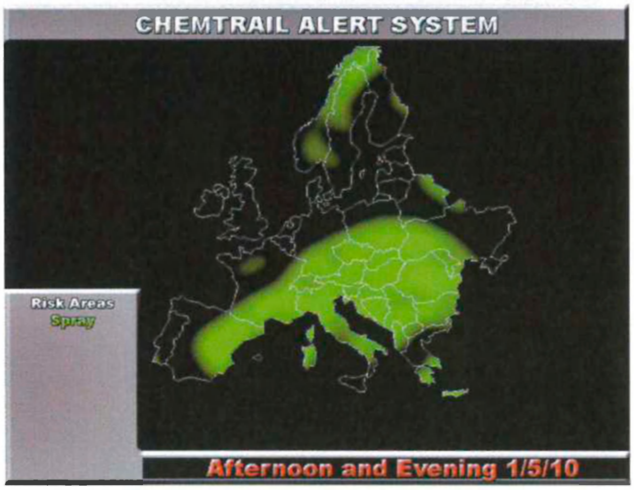
This map shows the European spraying scheme for June 6th 2008.[152]

The spraying schemes seem to be organized in a logical pattern so that the whole of Europe is covered in a 3-day period:



152 By courtesy of Kevin Martin, meteorologist.





The last maps with spraying schemes on the Southern California Authority website, January 6th 2010.[153]

The existence of such documents highlights the discrete but heavy involvement of governments at top level in climate control projects, which are hidden for the public for the obvious reason that the actual state of the planet is much worse than admitted through media channels. Indeed, scientists are seeking to counter with an ever louder sounding voice of climate engineering the scenario of a 3°C-increase in surface temperature, coupled with a more than doubled CO_2 output by the year 2100 – data that has been transmitted to the IPCC in 2005.[154] According to Mark Lynas, author of the book 'six degrees', the critical mass to induce cataclysms on planet Earth is a temperature increase of 2.5°C. Once beyond this point very volatile and unstable weather conditions on a global scale are expected, triggering unseen social unrest and martial law, chronic shortages of water and food and widespread destruction – especially in low lying areas.[155] This is exact the type of scenarios that various governments are trying to prevent by means of geo-engineering though production of artificial Cirrus clouds in order to keep the temperature increase within limits, thus enabling continuation of business on the planet 'as usual'.

A press statement, released on September 4th 2009 by 5 top economists including 3 Nobel laureates just before the opening of the later (deliberately) torpedoed Copenhagen top climate summit, in which climate engineering is considered as the 'most cheap and

153 http://www.scwxa.org
154 Idem as footnote 151, page 63.
155 Lynas Mark, Zes graden, onze toekomst op een warmere planeet, pages 129-193, Uitgeverij Jan Van Arkel, Utrecht, 2008.

rapid response' to global warming, confirms this point of view.[156] Stratospheric aerosol insertion receives a rating 'very good' in the list of possible options. All carbon taxes, which are now at the political negotiation tables, are considered as poor and useless for the safeguard of the planet – although they are a pretty good business. The full press statement is included in appendix 18.

At the time of public release of this research paper in May 2010 our investigation team comes to the conclusion that climate control programs, controlled by the military but approved by governments are silently implemented in order to avoid the worst case scenarios they obviously do not want. The two basic instruments are temperature control through generation of artificial clouds and manipulation of the ionosphere through ionosphere heaters. Both remain basically military combat systems with the option to go into the offensive if deemed necessary. However since several ionospheric heaters are installed on various places around the globe one can assume that there is wide co-operation between governments in order to reach the climate targets by 2025: controlling the weather and thus the planet.

Last but not least one can ask why staff of the university of East Anglia has deliberately manipulated climate data for the sake of the IPCC? Accidentally or not the beginning of the falsification of data series starts at the beginning of atmospheric seeding and the operational cycle of HAARP… It is also an interesting path to investigate if 'Climate Gate' is not an accident, but a well planned maneuver to gradually prepare the global population for their future on the planet.

5.3. MODUS OPERANDI FOR CLIMATE MODELLING THROUGH MODIFICATION OF CIRRUS CLOUDS:

5.3.1. Technique of modification of Cirrus clouds:

It has been adequately illustrated that Cirrus clouds do have a significant impact on temperature and precipitation on a specific spot on Earth. If one combines this knowledge with strategic plans and scientific studies as described in previous chapter it is only a matter of time before climate modeling through modification of Cirrus clouds will be used on a large scale, whether for peaceful or military purposes.

As explained in paragraph 4.2.2 aircraft engine emissions that develop into contrails, which form men made Cirrus under specific conditions, posses a global warming potential. Although they reflect incoming sunlight they also trap the long wavelength blackbody radiation released by the Earth, thus resulting in a net increase of global warming.[157] Therefore it is imperative to develop a reliable technique that permits heat escape through the atmosphere, taking into account the albedo characteristics of the planet.

Both U.S patents 5,003,186 for stratospheric seeding and 3,899,144 claiming a powder contrail generator for radiation scattering, as well as the research work of David L. Mitchell and William Finnegan claim that global warming can be reduced by seeding the upper atmosphere by the following combination of metallic particles:

156 Top economists recommend climate engineering, Press statement, September 4th 2009, Copenhagen Consensus Centre.
157 U.S. patent 5,003,186, Stratospheric Welsbach seeding for reduction of global warming, Background of the invention, March 26th 1991.

U.S. patent 5,003,186, Stratospheric Welsbach seeding[158]	U.S. patent 3,899,144 Powder contrail generation[159]	D. Mitchell and W. Finnegan research paper: modification of Cirrus clouds[160]
One of more oxides of metals (not specified), particle size 10 to 100μ Aluminum oxide Thorium oxide Welsbach material	85% TiO_2 (e.g. Dupont R-931, median particle size 0,3μ) 15% colloidal Silica (e.g. Cabot S-101 Silanox, median particle size 0,007μ) Silica gel (e.g. Syloid 65, average particle size 4,5μ)	A pressed composite mixture of Bismuth tri-iodide (BiI_3), potassium perchlorate ($KClO_4$), Aluminum (Al) and gilsonite (a natural hydrocarbon)

As explained in the previous chapter the delivery mechanism is aviation. The stratospheric Welsbach patent suggests particle seeding by dispersal from aircraft at an altitude on the order of 10 km, but this is within the troposphere where airliners routinely cruise - except at polar latitudes.[161] D. Mitchell and W. Finnegan are even more specific about this: "with the delivery process already existing, this geo-engineering approach may be less expensive than other proposed approaches."[162] This implies that the mechanism for widespread spraying of metallic particles through commercial aviation is already in place since a considerable long time. The 'other proposed approaches' may be the technology as claimed in patent 3,899,144, iron ocean fertilization of 1975 or even HAARP (1991). Refer to appendix 19 for the full text of this research paper.

Adding tiny metallic particles to aviation fuel Jet A-1 or the military JP-8 or JP8+100 have a specific purpose. They are characterized by wavelength dependent emissivity or reflectivity, in that said materials have high emissivity in the visible and infrared wavelength region and low emissivity in the near infrared region. Such metals are also referred to as Welsbach material in the 5,003,186 patent. By seeding these metals in the upper troposphere and stratosphere the particles remain suspended for some time in the air and provide by their nature a mechanism for converting the blackbody radiation in the near infrared region into radiation in the visible and infrared wavelength so that the heat energy may be reradiated out into space, thus reducing global warming due to the greenhouse effect.[163]

On the question if this technique is adequate for reduction of global warming one can only state that the primary examiner of the patent bureau only delivers U.S patents if the inventors can sufficiently demonstrate that the invention effectively works. Moreover secrecy orders may be issued if they are deemed detrimental or vital to national security. In some cases the government can even confiscate a patent ('John Doe'). A list of military patents, secrecy orders and John Doe's for the period 1988-2009, as well as an example of secrecy order letter, are contained in appendix 20.

A last consideration is that the metal particles must remain suspended in the atmosphere for a considerable long time in order to be effective. Patent 5,003,186 claims that the particles may remain in suspension for up to one year.[164] D. Mitchell and W. Finnegan use the same logic with a much shorter residence time (1 up to 2 weeks) but far sufficient to produce 'artificial' Cirrus clouds that enable climate modeling with temperature and precipitation as instruments.

158 Idem as footnote 157
159 U.S. patent 3,899,144, Powder Contrail Generation, August 12th 1975.
160 Michell D.L. & Finnegan W., Modification of Cirrus clouds to reduce global warming, Desert Research Institute, Reno, USA, October 30th 2009.
161 Idem as footnote157.
162 Idem as footnote 160.
163 Idem as footnote 157.
164 Idem as footnote 157, page 5.

An argument that is used in almost all these publications is cost effectiveness hence atmospheric seeding through aviation seems to be the cheapest option for geo-engineering. It comes at no surprise that the number of complaints of civilians about persistent Cirrus clouds and conspiracy theories such as 'chemtrails' are on the increase. In the scope of the extensive U.S. weather modification project through history it is clear that Hughes Aircraft Company must have performed extensive testing before the patent was awarded and implementation of this technology is already finalized – cost effective, efficient on short term, with or without active co-operation of air crews, in short 'perfect'.

5.3.2. Legal aspects of climate modeling through aviation:

The question arises about the legal aspect of these spraying actions, especially in Europe since it may be an infringement of the sovereignty of the airspace of different countries. For example the Belgian airspace (FIR and UIR EBBU) consists of the national territory, part of the North Sea and Luxemburg.[165] Although all aircraft that emit a mixture of exhaust gases and metallic particles legally operate in controlled airspace on a prior approved flight plan the consideration has to be made if formation of men made Cirrus clouds over France that drift within Belgian airspace would present a violation of the law. However, as long the existence of the technique of cloud generation through contrails is officially denied this is not an issue.

In the United States things are quite simple since it is a vast country and spraying is considered legal according public law.[166] Rather intriguing is the space preservation act proposal of 2001, which was rejected on April 19th 2002 after an unfavorable executive comment received from the DOD. As a result of this seeding the atmosphere through aviation can be considered as legal in this country. The unrevised proposal included a permanent ban on 'exotic space weapons', which included ultra low frequency weapons, environmental & climate weapons and chemtrails – the only existing document where this phenomenon is explicitly mentioned.[167] The bill was re-written in less unusual language with omission of these 'exotic weapons' before submission to the committee. Websites that systematically deny the existence of climate manipulation programs state that congressman and sponsor Dennis Kuchinich did not even write the bill or read a document written by 'UFO-enthusiasts' until too late.[168] However it shines some light on the professionalism that reigns in some government circles. A copy of the unrevised Space Preservation Act is included in appendix 21.

Spraying programs in Russia and the People's Republic of China are legal since they are standard procedure for major political rallies and parades.

Some interest groups however do put the legality of geo-engineering as a solution for global warming into question. One of them is the ETC-group, a technology watchdog with HQ in Canada. They warn against the rollout of geo-engineering as plan B after the failure of the Copenhagen climate summit in 2009 and point out that Bill Gates and Richard Branson are very keen to experiment with 'fast, cheap and imperfect' geo-engineering technologies – 'no matter what happens to this planet'. According to the ETC-group the very fast developing geo-engineering lobby has no mandate and no right to manage solar radiation on behalf of anyone.[169] That is very much true. Refer to appendix 22 for the full text of the ETC Group news release.

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165 Aeronautical Information Publication Belgium and Luxemburg CD-rom, AIP section ENR, issued by Belgocontrol, 2010.
166 U.S. Public law 95-79, title VIII, Sec. 808, July 30th 1977.
167 HR2977: Space perservation act of 2001, 107th congress 2001-2002.
168 http://contrailscience.com/kucinich-chemtrails-and-hr-2977/
169 Top-down planet hackers call for bottom-up governance, ETC Group news release, February 11th, 2010.

5.3.3. Safety and health aspects of climate modeling through aviation:

According to D. Mitchell and W. Finnegan seeding the atmosphere with aerosols containing oxides of metals as part of a geo-engineering project have some drawbacks:[170]

- Increase of the rates of strategic ozone destruction.
- Higher costs of injecting sulfur compounds into the atmosphere.
- Decrease in solar radiation altering the hydrological cycle with more frequent droughts.
- Change in sky color from blue to white.
- Less solar power.

Change in precipitation patterns have already been covered in paragraph 4.3, confirming that climate modeling projects through aviation should be approached in a much more cautious way. Ozone depletion is a fact, which could effectively be countered if HAARP was to be used for more peaceful purposes. The change of color is probably the more frequent appearance of a milky sky, which is a totally unacceptable prospect if geo-engineering is to be used on a global scale.

According to official government sources, such as the U.S. Agency for Toxic Substances & Disease Registry (ATSDR), materials such as Aluminum that is used in the aerosol mix are always present in virtually all food, air, water and soil and therefore exposure is usually not harmful and there are no known carcinogenic effects.[171] The same logic applies when researching the effects of Barium.[172] The questions arises how extremely high concentrations of Aluminum and in a lesser extend Barium, measured in the center of Paris (for example PTE = Paris Tour Eiffel) in November 2008 and included in appendix 23 should be interpreted as there are no fixed standards to determine an alarm level for this type of contamination.

However there is ample evidence that aircraft engine emissions – even without the addition of an aerosol mix - pose a threat to public health, although its effects are minimized by the industry as a result of corporate profit, conflicts on interests and ineffective control by government and regulating authorities.[173] The aerotoxic syndrom, which has first been recognized in 1999, affects an increasing number of flight crews and cabin personnel. It is a term that encompasses the following symptoms observed by crews who have been exposed to hydraulic fluid, engine oils or mists as a result of the circulation of bleed air in the pressurized cabin:[174]

- Symptoms of dysfunction in neurological function, immediately after intense exposure, including loss of positional awareness, vertigo and loss of consciousness. If these symptoms occur to a pilot there is a significant aviation safety problem.
- Symptoms of skin, eyes, nose and respiratory irritation immediately after exposure. Further exposures exacerbate the symptoms, often leading to other respiratory and cardiovascular effects.
- Symptoms of gastrointestinal discomfort immediately after exposure. While these recede with cessation of exposure there is a suggestion that nausea and diarrhea can persist.

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170 Michell D.L. & Finnegan W., Modification of Cirrus clouds to reduce global warming, Desert Research Institute, Reno, USA, October 30th 2009.

171 ToxFAQ for Aluminum, Agency for Toxic Substances & Disease Registry, September 2008.

172 ToxFAQ for Barium, Agency for Toxic Substances & Disease Registry, August 2007.

173 www.aerotoxic.org/index.php/about-aerotoxic-syndrome , Is the aviation industry adressing the issue.

174 Winder C., Fonteyn P. And Balouet J-C, Aerotoxic syndrome, a descriptive epidemiological survey of aircrew exposed to in-cabin contaminants., J Occup Health Safety – Australia & New Zealand 2002, 18(4) 321-338.

- Some symptoms of impairment of neurophysiologic function immediately after exposure, such as headache, dizziness, disorientation and intoxication. These symptoms become more debilitating after time with loss of cognitive function and memory problems emerging.
- General symptoms of exhaustion to chronic fatigue, with suppression of the immunity system with food intolerance, allergies and chemical sensitivities (MCS or Multiple Chemical Sensitivity) some time after exposure.

The aircrews in this survey had incidences of symptoms at much higher rates than population backgrounds, suggesting that they were unhealthier than the general population. However, since pilots and cabin crew undergo routine medical checks the level of fitness and health in such individuals should be better than population norms.[175] Various governments and regulating authorities have commissioned research on this subject, but so far have not been 'able to conclusively prove a link between contaminated cabin air and chronic health problems'. [176] The full text of this research paper is included in appendix 24.

As the aerotoxic syndrome is a joint result of leakage of hydraulic fuels and engine oils there is other evidence that jet fuel itself is detrimental to health. Extensive animal testing on monkeys, rats, mice and dogs by the U.S. air force in 1993 – exposing them to then now obsolete JP-4 and JP-7 jet fuels showed decreased liver weights, red blood cell fragility, depressed activity, infertility and an increase in inflammations that sometimes resulted in cancer and subsequent death.[177] Refer to appendix 25 for an excerpt of this survey. There are no research papers released on the health effects of JP-8 or JP-8+100 military jet fuels but one can assume they are identical to those described in the 1993 paper.

These research papers illustrate that aircraft engine emissions, whether combined with aerosols or not, are a concern for public health and action should be taken by the scientific society to perform additional research on the effects of nano sized particles on humans and in general our eco-systems.

175 Idem as footnote 174, page 336.
176 Idem as footnote 174.
177 TP76-c2 Fuels on animals, Jet fuels JP-4 and JP-7, Health effects, 1993.

6. CONCLUSIONS AND RECOMMENDATIONS

The secretary of defense may conduct tests and experiments involving the use of chemical and biological agents on civilian populations.

Public law of the United States, Law 95-79, title VIII, Sec.808, July 30^{th} 1977.

6.1. CONCLUSIONS AND RECOMMENDATIONS:

When combining the knowledge of the formation of contrails, the effects of Cirrus clouds on climate, the historical records of weather manipulation programs, the scientific studies on geo-engineering through modification of Cirrus clouds, the available and patented technology coupled with reactions of pilots on the internet one can only come to the following conclusions:

1. Manipulation of climate through modification of Cirrus clouds is neither a hoax nor a conspiracy theory, but currently the best option in geo-engineering considered by decision makers to counter global warming. The impact of production of artificial Cirrus clouds on temperature and precipitation patterns is supported by adequate hard scientific evidence.
2. The ambition of the United States is to control the weather by the year 2025, both for civil and military purposes (offensive and defensive strategies). This research paper contains a proven track record to support that statement.
3. The technology to organize spraying actions on a global scale is widely available. Both civil and military aviation is used for that purpose. The mix, containing oxides of metals and chemical components, can either be dispersed through special designed pods or directly incorporated into the jet fuel. This research paper is well documented in this respect.
4. Since the patents are owned by the main defense contractor for the U.S. armed forces (Raytheon) or the U.S. department of defense itself and given the history record it is obvious that current climate manipulation programs are organized and directed by the United States government.
5. The spraying actions in Europe are only possible with prior approval and intense co-ordination on top government level and industry on executive level. The general public is intentionally kept unaware of the existence of such projects.
6. Although the spraying actions may be considered legal these actions may have a potential detrimental effect on health. There is sufficient scientific evidence available in this research paper to support this thesis.

It is not the purpose of this research paper to give a moral appreciation of these actions. Nevertheless the investigation team unanimously comes to the following recommendations for the future:

a) Artificial Cirrus clouds should be classified as a separate cloud genus by the WMO. Additional scientific research with the effects on nature and public health on this subject should be considered. Results –whatever the outcome- should be made public.

b) It is unacceptable that the Awacs aircraft fleet under NATO operates under a Luxemburg civil registration without complying with civil aviation regulations. This is a flagrant violation of the law and this should be corrected in the near future. Given the very unfavorable engine emission ratios of this aircraft retrofitting of these engines should be considered as soon as practical.

c) When considering a legal case it is better to sue an industrial group, such as Raytheon, rather than a government agency. It is clear for us that the responsibility of Raytheon in this respect is far reaching with the creation of a monopoly in climate modeling and weather as a geo-engineering or military instrument. If possible an international ban should be placed on such weapons.

d) Although the existence of weather modification projects have been illustrated in an adequate way in this research paper it is now the duty of a serious politician on any level to make enquiries to the government for public release of these spraying schemes through aviation. It is mandatory that such statement should include the reason why such operations are conducted. It is not an option to hide behind the motive of national security.

The investigation group has performed the research meticulously with maximum integrity and we hope that our intervention will reveal the truth about climate manipulation, exposing the real reasons to the general public, which has the basic right to know. We also hope this research paper will contribute towards a more peaceful world. Last but not least we thank the Belfort group for its courage and wish them maximum success in public divulgence of this document.

In the name of our planet, Agent Orange

On behalf of the Belfort-group and of humanity as a whole
I congratulate this team of 'inside' experts for doing an
outstanding job in producing this scientific evidence based
and very well documented report.
Although for security reasons I do not know their identity
I thank these brave persons from the bottom of my human being.
I am sure that their engagement was driven by their conscience,
their knowledge, their desire for the truth, their sense of
responsibilaty for Mother Earth and all her creatures
and above all their love to Love, which is definitely
the only engine of Life itself.
May this document contribute to the wake-up of mankind
and the transformation of our species to become again
what we were always ment to be: god-like, spiritual beings...

Ring the bells, that still can ring
Forget your perfect offering
There is a crack in everything
That's how the light gets in
Leonard Cohen, the Anthem.

May God help us all...

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9940 EVERGEM (BELGIUM)
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00-32-9-357.33.36

I, 1

APPENDIX 1

I, 2

Aircraft Engine Speciated Organic Gases: Speciation of Unburned Organic Gases in Aircraft Exhaust

EPA United States Environmental Protection Agency

FEDERAL AVIATION ADMINISTRATION

I, 3

Aircraft Engine Speciated Organic Gases: Speciation of Unburned Organic Gases in Aircraft Exhaust

Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

and

AEE-300 - Emissions Division
Office of Environment and Energy
Federal Aviation Administration

EPA-420-R-09-902
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I, 4

Aircraft Engine Speciated Organic Gases: Speciation of Unburned Organic Gases in Aircraft Exhaust

W.B. Knighton, S.C. Herndon, and R.C. Miake-Lye

Purpose and Scope: The FAA and EPA are evaluating the methodology to quantify Hazardous Air Pollutants (HAPs) emissions from commercial aircraft engines, to be used when an aircraft HAPs emissions inventory is requested. Central to the methodology is a singular HAPs speciation profile. The final HAPs speciation profile will be:

- Nationally consistent,
- Supported by state-of-the-science data,
- Representative of today's commercial aircraft fleet, and
- "Living" to continue to reflect the state-of-the-science as studies are conducted and new data becomes available.

A second outcome of this effort is to evaluate and, if necessary, update the factors needed to convert between total unburned hydrocarbons (HC), volatile organic compounds (VOC), and total organic gases (TOG).

The scope of this work is to update the current HAPs profile that exists for commercial aircraft engines, using recent HAPs measurements conducted on more modern commercial aircraft engines. The original HAPs profile has been in existence unchanged for over 2 decades, based upon a single 1984 measurement campaign by Spicer et al.[1] To support the update of the existing HAPs profile, consolidated data from Spicer and more recent measurements (EXCAVATE, APEX) will be investigated and discussed in this document. Important questions to address in this scope of work are: how to combine all of the data sets into a single profile given the various methods used to collect the samples; and how to address combustor technologies, etc. not yet tested. We still have very limited data to work with at this time, which limits the conclusions we can make, so it is necessary to be mindful of these questions as new HAPs data becomes available in the future and we endeavor to update this methodology.

Introduction: Aircraft gas turbine engines are designed to burn their hydrocarbon (HC) fuel efficiently, since any inefficiency translates into carrying more fuel, a greater take-off weight, and a steeply rising cost of operation as efficiency decreases. Because most of the fuel is consumed at higher power settings and most of the operational time is spent at cruise, for power settings of cruise and above most engines convert significantly more

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[1] HAPs profile No. 1098 in EPA's SPECIATE database. http://www.epa.gov/ttn/chief/software/speciate/index.html Composite profile developed from data for a CFM-56 jet engine fired with JP-5 fuel at idle, 30% thrust and 80% thrust. Data collected by GC/MS and DNPH analyses were combined according to average LTO cycle times obtained from AP-42. Spicer, C. W., et al., Battelle Columbus Laboratories, Composition and Photochemical Reactivity of Turbine Engine Exhaust, Report No. ESL-TR-84-28, Prepared for Air Force Engineering and Services Center (RDVS), Tyndall AFB, FL, September 1984.

I, 5

than 99% of the fuel through complete combustion to carbon dioxide (CO_2) and water (H_2O). At idle conditions, much less fuel is consumed and, in the interest of maintaining stable combustion at lower power conditions, some sacrifice in combustion efficiency occurs even though this inefficiency is still only a percent or so. Any combustion inefficiency of HC fuel will result in emissions of some combination of CO and incompletely oxidized HCs, as well as some carbonaceous particles.

From the point of view of understanding the combustion process, knowing the combustion efficiency is important since any HC emission represents an inefficiency in converting fuel to CO_2 and H_2O. In order to understand the environmental impact of the emissions, it is important to quantify the amounts of the emitted species, especially those that are deemed highly toxic or carcinogenic. The US EPA considers a number of HCs (among other pollutants) as HAPs, and quantification of levels of these species takes on a special importance. This report will discuss the emissions of HAPs from aircraft engines and how the speciation of the HC emissions relates to levels of the various HAPs present in aircraft exhaust.[2] Since the concentrations of HCs and HAPs are highest in the exhaust at low power conditions, the emphasis will be on measurements under such conditions.

Components of PM emissions from aviation engines may also be classified as Hazardous Air Pollutants, but PM emissions are measured and analyzed very differently than gaseous emissions, and are not discussed in this document. Much work is currently being directed at identifying measurement approaches and resolving sampling issues for aviation gas turbine engine PM emissions (e.g. the APEX and related campaigns), and data characterizing PM emissions from a variety of commercial aircraft gas turbine engines is being accumulated.

Background: Several studies have attempted to document the speciation of the HCs emitted from aircraft engines. Most notably, in the 1980s Spicer et al. (Spicer, Holdren et al. 1994) performed a series of studies on a set of military engines using a variety of analytical techniques to quantify a wide range of HCs. Subsequently Gerstle et al. (Gerstle, Virag et al. 1999) examined another set of military aircraft, with a similar set of analytical techniques. Most recently, a set of studies initiated by NASA called Aircraft Particle Emissions eXperiment (APEX), and supported by a wide range of sponsors (NASA, FAA, CARB, EPA, DoD …) has focused attention on commercial aircraft Particulate Matter (PM) emissions (Wey 2004; Onasch, Jayne et al. 2006; Wey, Anderson et al. 2006; Lobo, Hagen et al. 2007), using a wide range of analytical techniques. These studies also included HC gaseous emissions analysis. Some of the techniques employed in APEX1-3 overlap with the earlier tests, but also some more advanced (faster time response/higher sensitivity) techniques were used during APEX.[3]

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[2] It should be noted that because a compound is considered hazardous it does not imply health or welfare effects at current levels, or that it is appropriate to adopt controls to limit the emissions of such a compound from turbine engine aircraft or their fuels.

[3] APEX was the collaborative research effort of NASA, EPA, DoD, and the FAA. The main objective of the APEX research was to characterize both gaseous and particulate emissions to advance the understanding of emissions from commercial aircraft engines. APEX1 was conducted in April of 2004 with a NASA-owned DC-8 aircraft equipped with CFM-56-2C1 engines. APEX2 was conducted in August 2005 for typical in-use aircraft engines (CFM56 engines on B737 aircraft), APEX3 testing was conducted

I, 6

The range of experiments and the variety of techniques employed can be used to provide greater confidence in the HAPs emissions measurement data, and to allow assessment of which results can be verified by multiple techniques. In addition, one engine type, a CFM56 (a high bypass turbofan engine), was part of both the Spicer and APEX studies, so that a most direct cross comparison can be made.[4]

The comprehensive measurements of Spicer et al. (Spicer, Holdren et al. 1994) have provided valuable data for the CFM56-3 and the TF-39 (forerunner to the General Electric CF6 class of high bypass turbofan engines).[5] These measurements were conducted using a mixture of on-line instrumentation and canister sampling with off-line analysis developed from a prolific program of military engine emissions characterization. This work chose to report values as ppmC present in the exhaust. The data labeled 'idle' in this work was conducted at nominal 'ground idle' and does not reflect the ICAO definition of idle, also called 7% of rated thrust. The Spicer et al. work finds that 40% of the organic gas mass is accounted for by the compounds, ethene, formaldehyde, propene, ethyne and methane.

In a report to the US Air Force, Gerstle and co-workers (Gerstle, Virag et al. 1999) reported HC emission rates for several engines not included in the ICAO databank, as well as some emissions from auxiliary power units. Some of the military engines addressed in this study represent older engine technologies that are no longer represented in the commercial fleet and, as such, there may be issues regarding combustion efficiencies at low power conditions that may cause significant differences in emissions due to raw fuel contributions to the HCs emissions at low power (personal communication Will Dodds, GE, and KBE, February 2007 et seq.).

A more recent series of measurements have focused on commercial engines. NASA's interest in charactering the emissions from commercial engines in dedicated engine tests was demonstrated during the EXCAVATE campaign. Anderson et al. (Anderson, Chen et al. 2006) measured the speciated organic gas emissions from a Rolls-Royce RB211-535-E4 engine (another high bypass turbofan engine) for two different fuel sulfur levels. A very comprehensive program continued with the APEX-1 campaign (Wey, Anderson et al. 2006) within which HAPs characterization was conducted with high time response on-line organic gas speciation using infrared fingerprint absorption spectroscopy and chemical ionization mass spectrometry for a CFM56-2C1 (Knighton, Rogers et al. 2007;

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in October and November of 2005 spanning a range of engines from a small business jet, through a modern regional turbofan, a single-aisle transport turbofan, to a large high bypass ratio turbo fan, representing five different engine types, some measuring more than one example. In all studies, exhaust plumes were sampled at the engine exit plane and several downstream measurement locations.

[4] CFM56 and the CFM logo are for CFM International, which is a joint company of Snecma and General Electric. Snecma is a French manufacturer of engines for commercial and military aircraft, and space vehicles.

[5] The General Electric TF-39 was the first high bypass turbofan engine, and it was developed for the Air Force back in 1965 for a new transport aircraft. Turbofan engines with a bypass ratio of 5 or greater are considered to be high bypass turbofan engines (Cumpsty, N., Jet Propulsion, Cambridge University Press, 2002, p. 46.). Bypass ratio is the ratio between the mass flow rate of the air drawn in by the fan, but bypassing the engine core, to the mass flow rate passing through the engine core (Cumpsty, loc. cit.).

Yelvington, Herndon et al. 2007). Time integrated LTO cycle data were also collected at the same time (Kinsey et al, document in preparation). An analysis of the JETS/APEX-2 (Lobo et al., 2007)[6] and APEX-3 datasets is forthcoming (Timko et al., in preparation).

In all of the APEX dedicated engine tests, measurements were made at both the engine exit plane and in the plume at a downstream location (nominally 30 m for an intermediate engine size such as a CFM56). It is important to note that the measured HC profile is relatively consistent regardless of measurement location. In the ensembles of data presented below, all of the various distances, fuels, and power conditions below 30% of rated thrust are combined in demonstrating the tight correlations among HC emissions. Further, in the airport studies discussed next, much further downwind measurements also indicated no change in the relative concentrations of species, although as the exhaust continues to dilute, the species present as very small fractions of the total profile begin to fall below detection limits as distances increase further from the emission source.

In addition to dedicated engine tests, sampling from airports during routing operation have also provided useful data for HAPs emissions. Using analysis of wind-advected plumes sampled at Boston Logan International Airport, selected speciated organic gas emissions were characterized from in-use aircraft (Herndon, Rogers et al. 2006). Schürmann et al. (Schürmann, Schäfer et al. 2007) also measured volatile organic compounds using canister sampling of diluted exhaust in an operational taxiway area. They found that refueling activity altered the profile of hydrocarbons considerably. An analysis of the wind advected data collected at the Oakland GRE and taxiway/runway sampling is forthcoming (Herndon et al., in preparation).

All of the studies indicate that a wide range of combustion-related emissions are present in aircraft exhaust. Despite the long list of species present, a ranking of the species by concentration indicates that 15-20 species represent most (95% or more) of the emissions on the basis of concentration. A greater number of species are present at a fraction of a percent or smaller of the total concentration. Of the overall speciated mixture, a number of species can be considered HAPs, while another set may be significant to the overall level of VOC emissions but data indicating toxicity are lacking.

An important point to note is that no instrument measures all of the HC emissions. The fast time response instrument (Proton Transfer Reaction Mass Spectrometer: PTR-MS) used for HC measurements in APEX was focused on measuring relevant HAPs, and as such was not capable of measuring alkanes or acetylene. Since the PTR-MS is capable of measuring a wide range of HCs other than alkanes and acetylene, the measurement focus was on a list of species that were measurable by the PTR-MS, identified EPA HAPs species, and present in aircraft exhaust. Formaldehyde and ethylene were also not measurable with the PTR-MS, but were measured separately in APEX using IR techniques (Tunable Infrared Laser Absorption Spectroscopy: TILDAS). In the Spicer

[6] Additional data reported from JETS/APEX2, taken by the UC Riverside team, was not used to develop the jet aircraft speciation profile, because the compromised sampling system for that data source prevented a complete and high-confidence organic compound data set from being assembled from the UC Riverside data.

studies, a wide range of techniques was used, but no measurement of methanol was attempted, and none of the trimethylbenzenes nor several of C9-C11 aromatic species were identified with the techniques employed therein. In many of the studies, a Flame Ionization Detector (FID) was used to quantify the total "unburned hydrocarbons" (UHCs), but this is an imperfect estimation of the total emissions due to the FID's non-uniform response to different carbon-containing compounds. All this is to note that, while these several data sets provide very useful data on many individual compounds and their relationship to one another, arriving at an estimate of a total quantity by mass or by concentration is dependent on which species are included in the total. And, the measured species are determined by what measurement techniques have been employed.

Data Comparison: The most direct intercomparison between the earlier studies and the recent APEX mission is accomplished through the overlap with the CFM56 engine. Table 1 reproduces Spicer's speciation data for this engine (Spicer, Holdren et al. 1994) ranked in order of decreasing concentration. The first column lists the species present in the highest concentration, which represent about 95% of the total speciated non methane hydrocarbon (NMHC) emissions on a concentration basis as measured by Spicer. The highlighted species indicate those species measured by Spicer that were also quantified in APEX by PTR-MS (yellow) or TILDAS (green). In the first column, only acetylene and ethane are not highlighted. In subsequent columns, the sum of which represents 5% of the Spicer emissions concentration, a number of other alkanes also are not highlighted. These species, not measured by PTR-MS or TILDAS, represent about 1.4% of Spicer's total, and are not typically considered HAPs. It is worth noting that, of the species noted in the "EPA 14" and "FAA 10" HAPs lists that were developed based on relevant HC emissions from aviation engines (URS and FAA 2003), all of those species are in the highlighted (measured in both studies) elements of Table 1.

I, 9

Table 1. NMHC emission ratios for the CFM56-3 engine reported by Spicer et al. listed in decreasing magnitude. The first column represents 95% of the emissions on a molar basis. Green highlighted cells indicate compounds that are measured by TILDAS. Yellow highlighted cells indicate compounds that are quantified by the PTR-MS.

Compound	ER (mmole/mole)	Compound	ER (mmole/mole)	Compound	ER (mmole/mole)
ethylene	0.77	acetone	0.0089	1-nonene	0.0027
formaldehyde	0.572	C5-ene	0.0072	propane	0.0025
acetylene	0.211	2-methylpentane	0.0066	1-CH_3-naphthalene	0.0024
propene	0.151	benzaldehyde	0.0062	hexanal	0.0023
acetaldehyde	0.135	1-heptene	0.0061	C5-cyclohexane	0.0023
acrolein	0.061	naphthalene	0.0059	ethylbenzene	0.0023
1-butene	0.044	C5-ene	0.0055	C4-benzene	0.0023
glyoxal	0.044	cis-2-butene	0.0052	o-xylene	0.0022
1,3-butadiene	0.044	styrene	0.0041	2-CH_3-naphthalene	0.0020
benzene	0.03	n-undecane	0.0040	C5-benzene	0.0020
methylglyoxal	0.029	n-pentane	0.0038	1-decene	0.0018
ethane	0.024	n-dodecane	0.0038	C13-alkane	0.0014
butanal/crotonaldehyde	0.019	m,p-xylene	0.0037	C14-alkane	0.0013
propanal	0.017	2-methyl-2-butene	0.0037	n-heptane	0.0009
1-pentene	0.015	1-octene	0.0034	n-octane	0.0008
1-hexene	0.012	n-decane	0.0031	n-nonane	0.0007
toluene	0.0097	phenol	0.0029	C12-C18 alkanes	0.0045

The highlighted sections in Table 1 indicate that comparisons can be made for the measurements of those species measured for Spicer's CFM56 and the several CFM56 engines measured in APEX. Those comparisons are listed in Table 2 as mass ratios, expressed as ratios of Emission Indices (EIs). The EI of a species is the mass of that species emitted in grams, divided by the mass of fuel consumed in kilograms (species g/kg fuel). The unhighlighted elements in Table 1 indicate that the APEX PTR-MS/TILDAS data set is missing those elements and no direct comparison can be made and are thus not included as rows in Table 2. The unhighlighted elements in Table 1 represent approximately 12% of the concentration in Spicer's list.

I, 10

Table 2. Compound EIs normalized to formaldehyde (EI_x/EI_{HCHO}) for low engine powers (4-15% rated thrust) evaluated as the slopes of plots of EI(x) vs EI(HCHO)

Compound	APEX 1 EI_x/EI_{HCHO}	APEX 2 EI_x/EI_{HCHO}	APEX 3 EI_x/EI_{HCHO}	Spicer et al. EI_x/EI_{HCHO}
Methanol	0.18	0.14	0.12	--
Propene	0.36	0.39	0.38	0.37
Acetaldehyde	0.32	0.36	0.36	0.35
Butene + Acrolein	0.30	0.45	0.48	0.36
Acetone + Propanal + Glyoxal	0.18	0.16	0.20	0.24
Benzene	0.15	0.17	0.16	0.14
Toluene	0.056	0.082	0.073	0.052
mass 107	0.088	0.138	0.103	0.089
mass 121	0.074	0.119	0.085	--
mass 135	0.035	0.074	0.051	--
mass 149	0.014	0.038	0.027	--
Naphthalene	0.018	0.034	0.020	0.044
Methylnaphthalenes	0.009	0.023	0.016	0.037
Dimethylnaphthalenes	0.0026	0.011	0.0083	--
Phenol	0.063	0.064	0.050	0.016
Styrene	0.020	0.035	0.023	0.025
Acetic acid	0.16	0.057	0.084	--

propene – quantified assuming that 68% all of the ion intensity measured at m/z43 originated originates from propene.
butene + acrolein – quantified assuming the m/z 57 signal is distributed as reported by Spicer et al. 45% butenes and 55% acrolein.
acetone + propanal + gyloxal – quantified assuming the m/z 59 signal is distributed as reported by Spicer et al. 12% acetone, 25% propanal and 63% glyoxal.
Mass 107 – quantified as p-xylene and represents the sum of o,m,p-xylene, ethyl benzene & benzaldehyde
Mass 121 – quantified as 1,2,4-trimethylbenzene and represents the sum of C_9H_{12} and C_8H_8O
Mass 135 – quantified using a single rate constant and represents the sum of $C_{10}H_{14}$ and $C_9H_{10}O$
Mass 149 – quantified using a single rate constant and represents the sum of $C_{11}H_{16}$ and $C_{10}H_{12}O$

However, as is noted by the first row of Table 2, Spicer did not measure methanol, which is approximately 5% of Spicer's total concentration, which would increase the HC total by that amount. There are also several other aromatic species listed in Table 2, which were not identified in the Spicer analysis. While these compounds would fall into the second two columns of Table 1 if they were included, and thus represent only a percent or so of the total concentration profile, they do represent a significant number of aromatic compounds. These several differences in the lists of species measured in these measurement studies highlight the uncertainty in working with any "total" emissions level: the "total" is only a sum of whatever species are included in the "total".

A longer list of species measured in the APEX campaigns but not measured by Spicer is included in the accompanying spreadsheet. In that spreadsheet, the additional species are color coded by blue (from PTR-MS) and yellow (from EPA's set of integrating measurements, Kinsey et al, manuscript in preparation).

I, 10

This spreadsheet also provides a normalized emission profile. This profile was developed based on Spicer's original speciation and carbon balance. Adjustments and additions were made, based on the new data available (all APEX1-3 data discussed in this report), but the measured species continue to make use of the original carbon balance. Thus, because of the longer list of species now quantified, these refinements to the speciation profile result in a decrease of the unidentified emitted mass from about 35% in the original Spicer work (34% if methane were included, but as discussed below, Spicer has shown elsewhere that the methane measurement was due to background methane and should not be included in the sum) to about 29% due to the additionally identified species and refinements to phenol and butyraldehyde/crotonaldehyde. Separate analysis of the total HC emissions by independent measurements during the APEX1-3 campaigns (J. Kinsey, personal communication) used time-integrated sampling over a range of power conditions. Because that approach is distinguished from the single power points measured by Spicer and the data presented here, precise agreement would not be expected due to different dependence on background levels and related data analysis issues. However, despite these potential differences, similar ratios of the sum of identified to the total HC mass were calculated using the time integrated measurements in APEX1-3 as compared to those of this revised profile, giving increased confidence in the overall HC mass balance presented with these data.

While the unidentified species mass has been reduced through this process, the composition of that unidentified mass remains an uncertainty. In the original Spicer profile, which used gas chromatography and various HC capture techniques, the unidentified mass could possibly include contributions from some of the species that were specifically identified. In other words, based on the original Spicer work, one could argue that some of the identified species may have been present in larger amounts than were reported because they may have also been contributing to the unidentified mass. That would be a result of some mass "sticking" to a GC column or a HC capture medium. The new additional data reduces that uncertainty considerably, since independent real-time data were collected which largely corroborated the Spicer profile. The combination of the original and new data provide good evidence that the identified species contribute to the profile at the levels measured and have little or no contribution to the unidentified HC mass fraction.

Table 2 compares the concentration of the particular species of interest to that of formaldehyde, which is one of the most prevalent emissions and serves as a useful reference species. This is done, rather than directly compare concentrations, since the combustion efficiency is highly dependent on precise fuel flow and power settings at low engine powers, with ambient temperature also having a significant impact on emission levels (Yelvington, et al.). Since engine operating point, ambient temperature, and related details are all slightly different from test to test, the combustion efficiency is also likely to vary from data set to data set. However, the relationship of the various emissions to each other is quite constant even though their levels may go up and down together.

I, 11

Figure 1 shows that this is true not only for the CFM56 measured in APEX1 and discussed by Yelvington et al. but it is also true for the several CFM56 engines measured in JETS/APEX2 and, indeed, is equally true for the wider range of different commercial engine types measured in APEX3. In fact, not only is it true that the speciation is invariant as a specific engine varies power and combustion efficiency, but for the range of commercial engines measured in APEX1-3 and the range of standard jet fuels used through those tests, the relationship between the various HC emissions, (i.e. the *speciation profile* shown here as individual species plotted versus formaldehyde, HCHO), is also invariant across these different commercial engine types: all of the curves lie essentially on top of one another. ***The invariance of the speciation profile across power settings, ambient temperature, and engine types for commercial engines is very useful for interpreting HAPs emissions from commercial engines.***

The range of fuels used in the diverse set of tests presented in Figure 1 suggests that fuel also has a minimal impact on the speciation profile. Fuel sulfur and aromatic content spanned a range of values across these tests, particularly when the APEX1 fuel sulfur additions are included. However dramatic changes in the hydrocarbon composition of the fuel, as might be encountered using alternative fuels like Fischer-Tropsch or bio-fuels, have not been explored in the set of data presented here.

The correlation of each of the individual species versus formaldehyde plotted in Figure 1 show that, for the three APEX campaigns, there are very tight correlations for the several species plotted. Species present in greater concentration (propene and acetaldehyde) have a tighter correlation than species at lower concentrations (benzene and, especially, naphthalene, which is a PAH and may begin condensing on PM emissions soon after leaving the engine, which might affect its gas phase concentration).

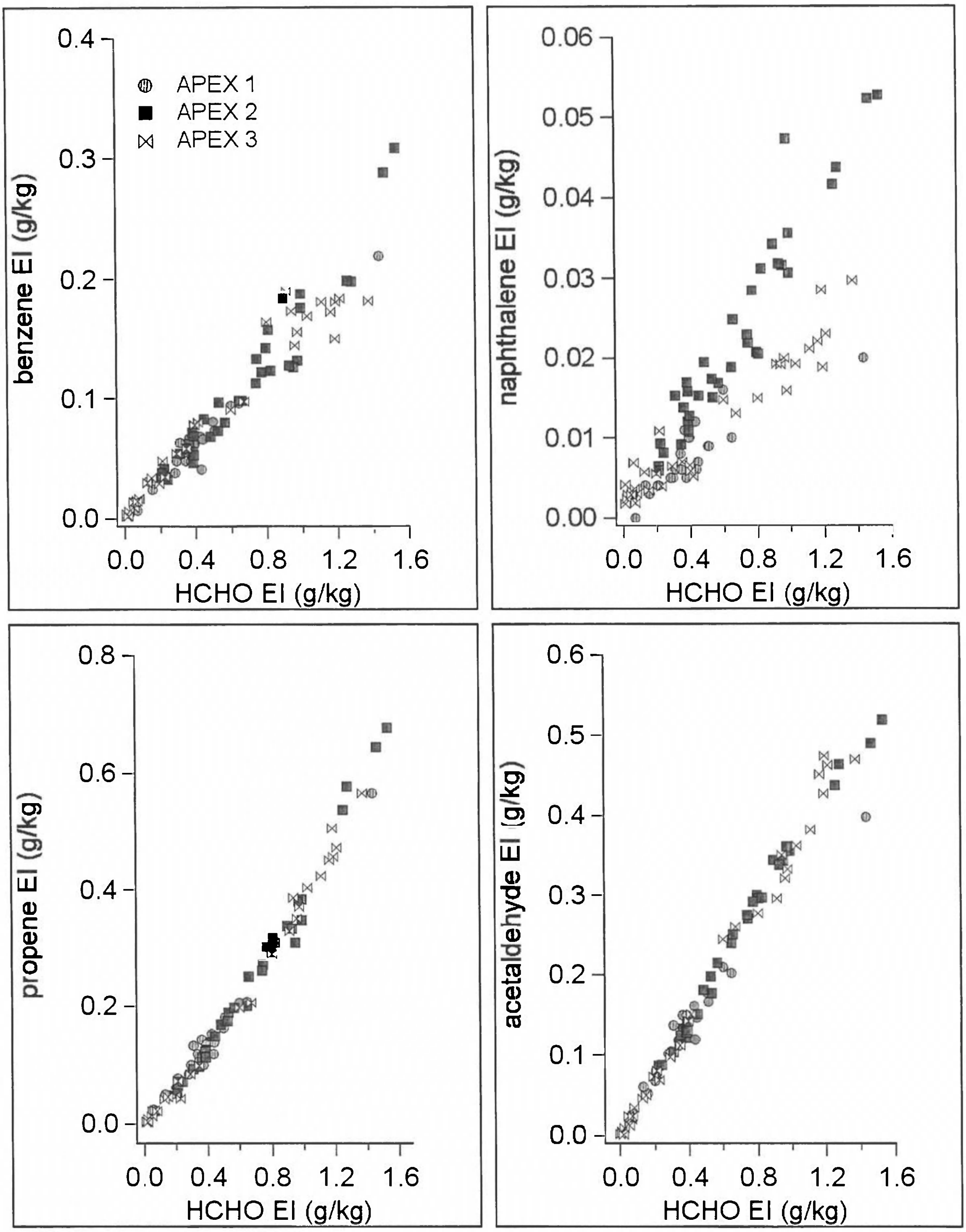

Figure 1. Correlation scatter plots of selected HC vs. HCHO emission indices measured on the 1-meter probe under low power, 4-15% rated thrust.

Table 2 provides the comparison between the speciation profile measured by Spicer and that from PTR-MS/TILDAS from APEX. The three data columns from APEX cover the CFM56-2C1 measured in APEX1, the several CFM56-3 and -7 engines measured in

APEX2, and an average over the set of engines (excluding the AE3007 for this analysis) measured in APEX3. For many species, especially those at larger concentration ratios, the variation among the various tests is no greater than the variation between APEX and Spicer. The speciation for these species appears to be very robust. Some of the more minor species show more significant variation, which may be partly due to measurement uncertainty and may be partly due to sensitivity to other variables such as minor fuel composition variations and so forth. It is worth noting that many of these smaller contributors represent less than 1% of the speciated concentration mixture.

One species of particular note is phenol. The APEX series of measurements indicate a concentration ratio three times higher than that of Spicer. That is the largest disagreement in Table 2 (excluding cases where a Spicer measurement is not available), and deserves further comment. While phenol represents only about 0.1% of the speciation concentration profile, it does represent a test of the ability to measure a minor species accurately. While further analysis might be warranted, phenol was measured by Spicer using canister capture to deliver the sample to the gas chromatographic measurement system. Given the significant differences indicated for this compound, wall losses might be suggested as a possible explanation for this unique discrepancy in the HC speciation.

The overall agreement between the Spicer and the APEX speciation profiles is shown in Figure 2. This is a direct comparison of the overall APEX speciation profile to that of Spicer for those species where the measurements are available in both studies. Except for phenol and the combination of acetone, propanal, and glyoxal (which, unlike phenol, is still within 2 sigma), all of the data are within the standard deviation of the measurements themselves to the unit line (the unity line represents perfect agreement).

I, 14

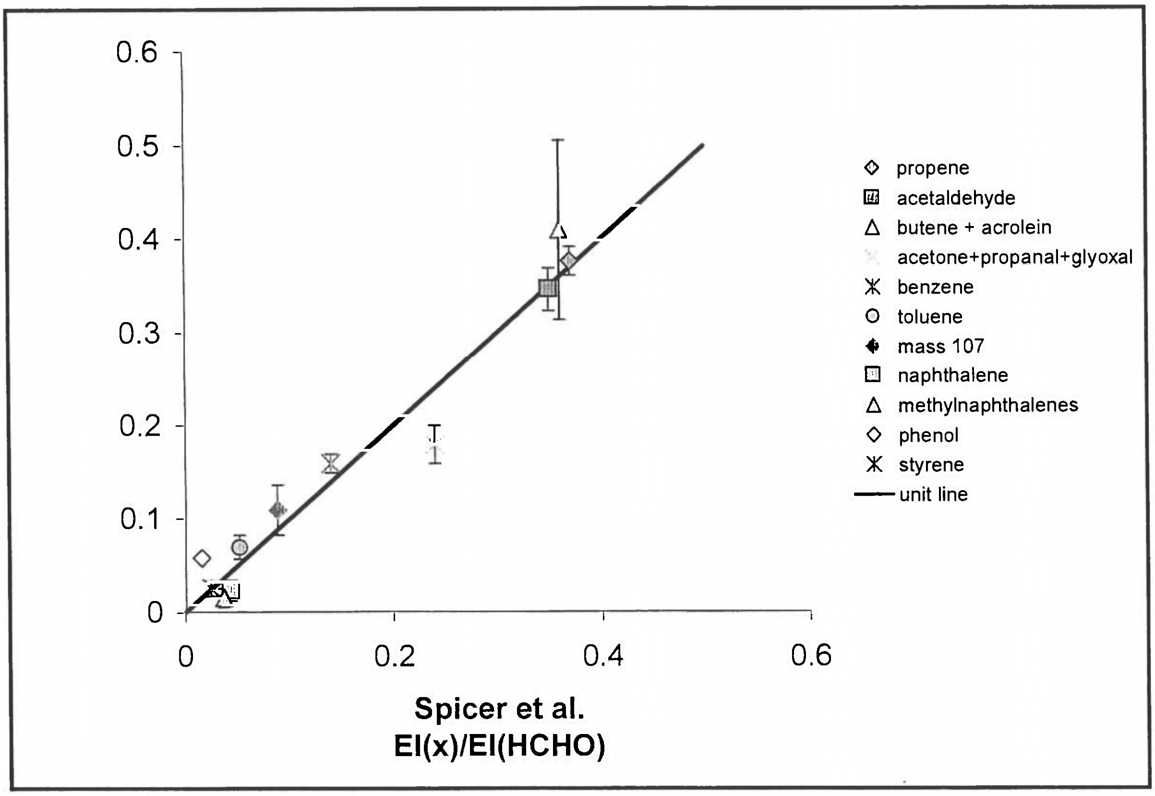

Figure 2. Correlation plot of normalized compound EIs derived from the APEX experiments versus that reported by Spicer et al. APEX data is derived from the slopes of the plots of EI(x) versus EI(HCHO) for data obtained at low power 4% - 15% rated thrust on the 1-meter probe. Error bars reflect the standard deviation of the three measurements.

The comparison of the various PTR-MS/TILDAS measurements across different engines in APEX3 provides strong support that the speciation profile is invariant across engine technologies for commercial engines. A similar question could be posed for the various military engines measured by Spicer and Gerstle. Initial analysis (data not shown here: KBE) indicates that there is much agreement between some of the relative amounts of relevant HAPs. Detailed analysis of the TF39 (a forerunner to the GE CF-6 engine) measured by Spicer is shown in Figure 3 comparing the speciation profiles for the TF39 with that of the CFM56 measured by Spicer, in analogy to what was shown in Figure 2 between the many engines of APEX1-3 and the Spicer CFM56-3. The speciation profiles for these two engines measured by Spicer, which received the careful analysis required for archival publication (Spicer et al. 1994), also support the contention that the speciation profile from aviation gas turbine engines is invariant across engine types.

I, 15

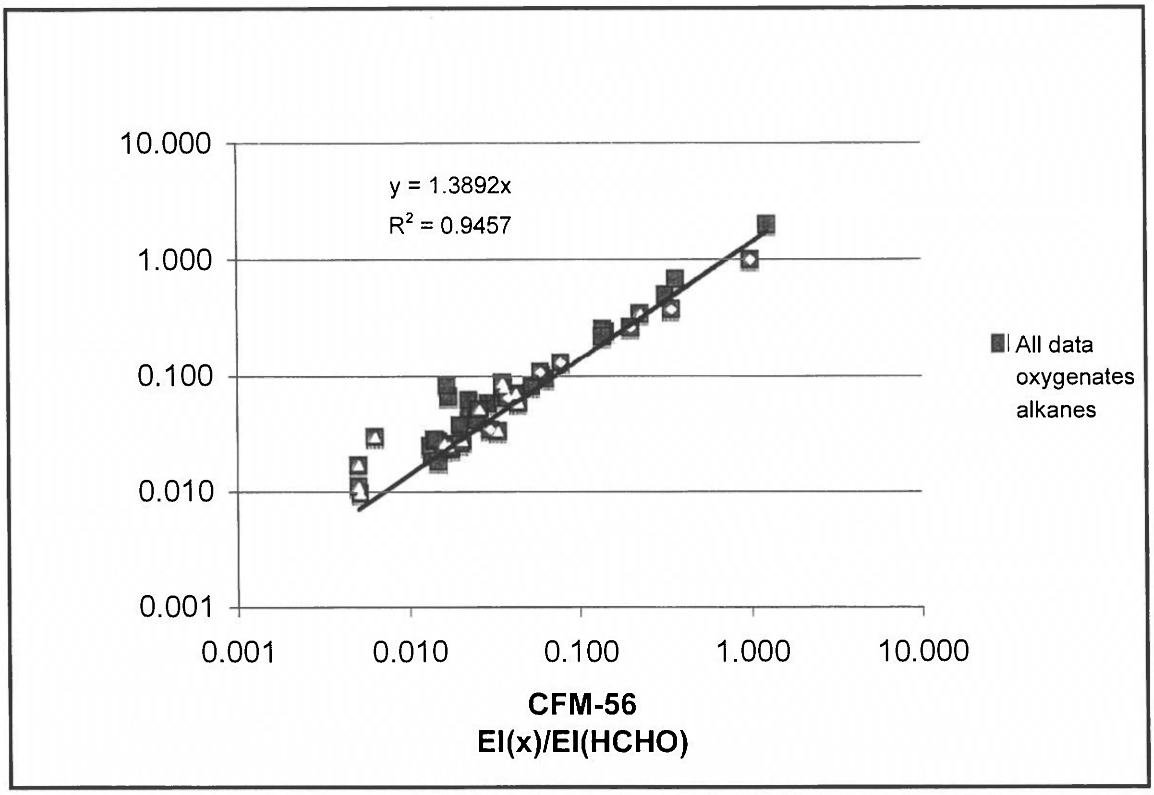

Figure 3. Correlation plot of normalized compound EIs for the TF39 vs. CFM56 engines at ground idle derived from the measurements reported by Spicer et al.

Discussion: The emissions of organic gases are controlled by combustion efficiency. The ICAO datasheets show a very clear trend of decreasing UHC emission indices from idle and approach to climb-out and take-off. There are strong dependences of the magnitude of UHC emissions between different engine models in the ICAO databank. The Yelvington et al. result from APEX-1 (Yelvington, Herndon et al. 2007) shows there is a strong dependence of the emissions of HCHO on temperature; that emissions increase at colder ambient temperatures, particularly for ground idle. This dependence is greater than estimated in the Boeing Fuel Flow Method-2[7] correction (DuBois and Paynter 2006).

Despite these strong dependences of the magnitude of UHC emissions on various factors, a remarkable and simplifying result is that the relative profile of organic gas emissions *near idle* does not have any such significant dependence, as presented in Figure 1. This has been demonstrated for various engines to be valid for conditions from ground idle up to ~15% of rated thrust. This invariant speciation profile demonstrates that despite large variations in the total amount of emissions, the ratio of benzene to ethylene, for example, is a relatively constant value among different conditions and engines.

[7] The Boeing Fuel Flow Method is a theory-based means of obtaining estimated emissions data at power conditions other than the ICAO specified power points by interpolating ICAO certification data.

One HC emission of particular note is methane (CH_4). This compound was measured by Spicer, but not in more recent studies. While methane is present in the exhaust of aircraft engines, it is present at levels below ambient levels for most power conditions (Spicer, Holdren et al. 1992, Wiesen et al, 1994, Vay et al., 1998). Indeed, in that reference Spicer notes "At power levels above idle, the exhaust is depleted in methane compared with the incoming air used for combustion. The methane concentrations observed in the engine exhaust are consistent with partial combustion of the atmospheric methane present in the inlet air, although some methane production during combustion cannot be ruled out." At idle the methane values in the exhaust during the Spicer were consistent with ambient levels, so any methane production must have been small enough to be within the experimental uncertainty or was balanced by methane consumption. Methane is not considered to be a significant emission from aircraft gas turbine engines burning Jet A, and is not included in the profile information provided here.[8]

At engine power conditions significantly higher that ~15% rated thrust, the engine combustion efficiency is so close to 100% that measurement of many HCs becomes difficult or impossible due to instrument detection levels for diluted exhaust gases (either with 1 m dilution probes or downwind sampling): the HC concentrations are too small to measure. Thus, when considering the total emissions contribution from a given aircraft operation, the amount of HCs is dominated by the low power conditions. Since the total emissions burden is the product of an emission index (g pollutant/kg fuel) times the fuel flow rate (kg fuel/sec) times the time in mode for that power condition, even the high fuel flow rates of take-off and climb-out cannot compensate for the very small emission indices for HCs and the short times in the take-off and climb-out power conditions.

The dominance of the low power conditions in determining the overall HC emission loading suggests that any changes to the HAPs profile above 15% power will have limited impact on the net HAPs loading. Since the emissions levels become too small to measure for many of the smallest percentage HAPs in the profile, a bound can be placed on how much their fractional contribution to the HAPs profile might be increasing as power increases. In lieu of specific data for these very small levels, a default of retaining the same profile as power increases beyond 15% could be suggested, which would be used for those powers above which the smallest contributors can be measured. An analysis of the potential errors introduced in using this default could be performed, however Figure 4 suggests that the limits of detection of the instruments, in combination with the rapidly decreasing overall HC emissions, will limit the overall uncertainties in the overall HC loading when using a low power HAPs profile.

Figure 4 demonstrates the relative importance of the elements of an LTO cycle by accounting for times in mode and emission indices for UHCs from the ICAO databank for a CFM56-3C1 engine (two engines for a 737-300). The LTO cycle in the figure reflects times in mode reported in the Boston Logan Airport 2005 Environmental Data

[8] When using this speciation profile in concert with reported certification HC emission indices, it is worth noting that ICAO CAEP Annex 16 Vol II makes no account for corrections to measured HCs due to ambient methane concentrations when reporting FID measurements for certification. Presumably ambient methane levels may be included in the certification FID measurements of EI HC unless otherwise noted.

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Report (Wilkins 2007). Essentially, it is a modestly adjusted set of times but the same power conditions as a standard ICAO LTO cycle. Whatever the variation in the speciation profile at the higher powers, the lower EIs at the high powers preclude a significant impact on the total emissions burden from the complete LTO cycle, at least in this first attempt to assess the speciated emissions. Variation in the HC speciation profile at higher powers are unlikely to have a significant impact on airport air-quality modeling or to risk assessment from the compounds that are HAPs.

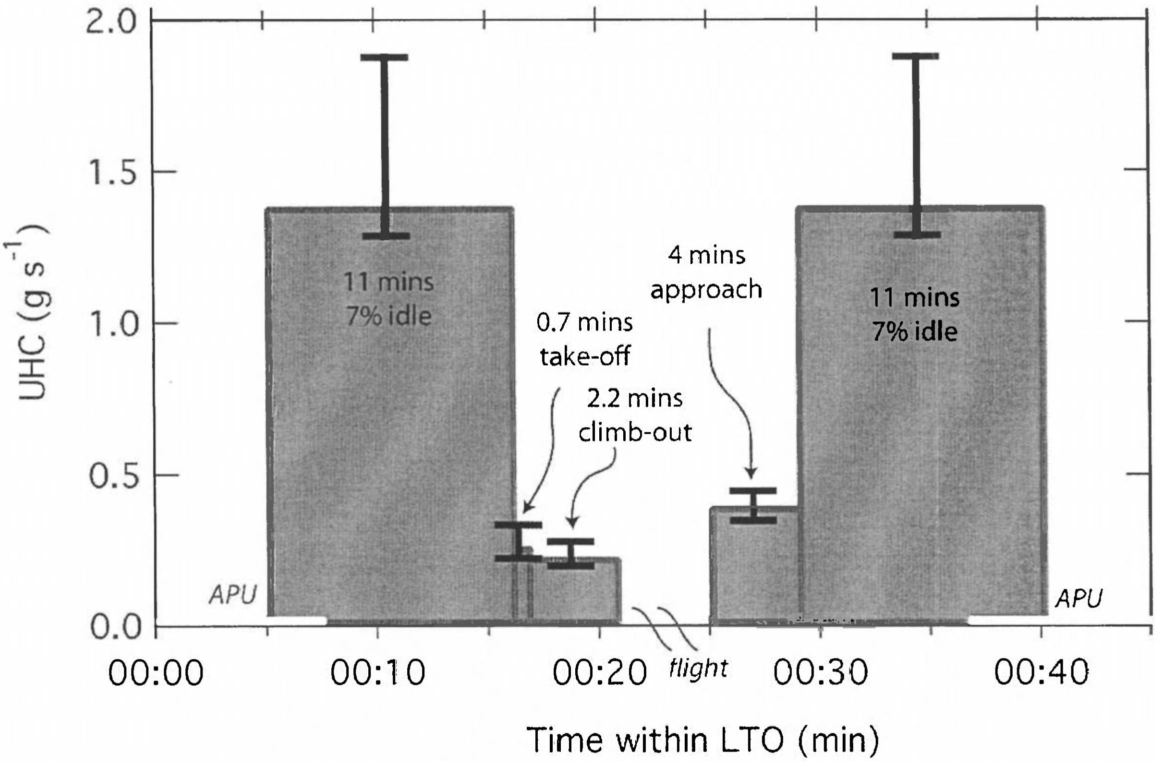

Figure 4. Emission Rate vs. Time in Mode. The estimated emission rate, coupling fuel flow and emission index for UHC for a CFM56-3C1. The LTO profile begins and ends with a 7.5 minute APU interval. In this figure the apparent area of the 'boxes' reflect the total emissions magnitude for the defined modes.

Relationship of Dedicated Engine Tests to Airport Measurements: Dedicated engine tests allow control of the engine operation. However emissions at airports are due to airplanes being operated as required to satisfy airline requirements. Table 3 compares normalized emission ratios (Species concentration/Formaldehyde concentration) for several APEX measurements and for advected plumes measured at Boston Logan, Zurich, and Oakland airports. While greater uncertainties might be expected in the advected plumes measured in a non-interference basis at airports, there is very good agreement between the emissions ratios measured in these disparate studies. In the advected plumes (last column) the error bars represent the width of the distribution of results. This uncertainty can be taken as an upper limit on the real variability in these ratios. When the detailed analysis of the instrumental contribution to this noise is complete, it will likely narrow the range of species variability, as opposed to instrument

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noise. This is possible because the observed distribution in this sample is nearly Gaussian.

Table 3. Speciated VOC Index Ratio (HCHO relative)

Compound	Spicer et al.	APEX-1	Logan	EXC	Zurich	APEX-2	OAK
						Staged	Advected
HCHO	1	1	1			*1	1
Acetaldehyde	0.35	0.24	0.26			0.37	0.31±0.09
C_2H_4	1.26	0.78		1*	1*	0.76	0.85±0.3
Propene	0.36	0.31		0.32	0.32	0.45	0.42±0.2
Butenes+Acrolein	0.36	0.45	0.25	0.45	0.26[&]	0.49	
Pentenes	0.11	0.31			0.11		
Benzene	0.14	0.14	0.11	0.08	0.11	0.18	0.15±0.08
Toluene	0.05	0.06	0.06	0.01	0.13	0.09	
1-ring Aromatics	0.28	0.48	0.3	-	0.39	0.73	
Styrene	0.03	0.03			0.04	0.04	
Naphthalene	0.04	0.01				0.04	

Table Notes:

All values are in units of grams of VOC per gram of HCHO, except for the EXCAVATE column, which is grams of VOC per gram of C_2H_4.

*The EXCAVATE and Zurich datasets have been normalized by the emission index for ethene in lieu of formaldehyde.

[&]The Zurich tabulation for Butenes+Acrolein assumes the ratio of Acrolein to the sum of the butene isomers is that found in Spicer et al.

The APEX-2, Staged aircraft column represents the average result for 'ground-idle' including the following engines; 3 CFM56-7B22, 1 CFM56-3B1, 2 CFM56-3B2.

Tabulated values in the OAK Advected column represent Gaussian fits to the distribution of measured compound to HCHO ratios. The error bar is one Gaussian width.

Next Step Recommendations: First, recent work has reinforced the overall speciation for commercial engine as measured by Spicer for the CFM56-3 engine. Both in comparison to the TF39 measured by Spicer and the wider range of commercial engines in APEX1-3, this speciation profile is insensitive to engine type, engine power condition, and ambient conditions, even though those parameters significantly impact the ***total*** amount of UHCs (or VOCs or total HCs, however one wants to add up a total). Other measurements (Gerstle and airport advected plume studies) are also consistent with the general invariance, ***near idle***, of this speciation.

Several modest uncertainties are present, particularly for species that are present in small quantities. These may be due to measurement uncertainties, or due to actual variations in emissions numbers themselves. Modest dependences on fuel composition or other unknown parameters may cause some of this variation. Most of these variations are within the uncertainties between studies or engines. One notable exception is the significant variation associated with phenol. The APEX studies all agree with one another for phenol, while Spicer is significantly lower. Wall losses in the canister

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sampling done by Spicer are a possible explanation for such a loss, but additional studies may be warranted to resolve this discrepancy.

For future work, two remaining questions should be kept in mind.

1. On which set of species do we need to focus to further refine the HAPs profile? (E.g.: [1] phenol discrepancy, [2] methanol and the several aromatics and long list of species present at a fraction of a percent of total mass not measured by Spicer et al., [3] questions regarding acrolein/butene etc.)
2. What is our approach to evaluating (and possibly revising) the UHC-to-VOC-to-TOG conversions?

With the completion of this analysis of Spicer and APEX data, we can offer the speciation profile provided in the accompanying spreadsheet for inclusion into the EPA's SPECIATE database.

Cited References:

Anderson, B. E., G. Chen and D. R. Blake (2006). "Hydrocarbon emissions from a modern commercial airliner." Atmospheric Environ. **40**(19): 3601-3612.

DuBois, D. and G. C. Paynter (2006). ""Fuel Flow Method2" for Estimating Aircraft Emissions." SAE Technical Paper Series **2006-01-1987**.

Gerstle, T., P. Virag and M. Wade (1999). "Aircraft Engine and Auxiliary Power Unit Emission Testing: Vol. 1." United States Air Force: IERA **RS-BR-TR-1999-0006**.

Herndon, S. C., T. Rogers, E. J. Dunlea, R. C. Miake-Lye and B. Knighton (2006). "Hydrocarbon emissions from in-use commercial aircraft during airport operations." Environmental Science and Technology **40**(14): 4406 - 4413.

Kinsey, J. S., Y. Dong, and D. C. Williams (in preparation 2008). "Characterization of Emissions from Commercial Aircraft Engines during the Aircraft Particle Emissions eXperiment (APEX)", U. S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, Research Triangle Park, NC.

Knighton, W. B., T. Rogers, C. C. Wey, B. E. Anderson, S. C. Herndon, P. E. Yelvington and R. C. Miake-Lye (2007). "Application of Proton Transfer Reaction Mass Spectrometry (PTR-MS) for Measurement of Volatile Organic Trace Gas Emissions From Aircraft." Journal of Propulsion and Power **23**: 949-958.

Lobo, P., P. D. Whitefield, D. E. Hagen, S. C. Herndon, J. T. Jayne, E. C. Wood, W. B. Knighton, M. J. Northway, R. C. Miake-Lye, D. Cocker, A. Sawant, H. Agrawal and J. Wayne Miller (2007). "The development of exhaust speciation profiles for commercial jet engines." Final Report, Contract No. 04-344, California Air Resources Board, Sacramento, CA, October 31, 2007.

Lobo, P., D. E. Hagen, P. D. Whitefield and D. J. Alofs (2007). "Physical characterization of aerosol emissions from a Commercial Gas Turbine Engine." Journal of Propulsion and Power **23**: 919-929.

Onasch, T. B., J. T. Jayne, S. C. Herndon, P. Mortimer, D. R. Worsnop and R. C. Miake-Lye (2006). "Chemical Properties of Aircraft Engine Exhaust Aerosols Sampled During APEX." NASA/TM-2006-214382 **ARL_TR_3903**: Appendix J.

Schürmann, G., K. Schäfer, C. Jahn, H. Hoffmann, M. Bauerfeind, E. Fleuti and B. Rappenglück (2007). "The impact of NOx, CO and VOC emissions in the air quality of Zurich Airport." Atmospheric Environ. **41**: 103-118.

Spicer, C. W., M. W. Holdren, R. M. Riggin and T. F. Lyon (1994). "Chemical composition and photochemical reactivity of exhaust from aircraft turbine engines." Ann. Geophysicae **12**: 944-955.

Spicer, C. W., M. W. Holdren, D. L. Smith, D. P. Hughes and M. D. Smith (1992). "Chemical composition of exhaust from aircraft turbine engines." Journal of Engineering for Gas Turbines and Power **114**(1): 111-117.

Timko, M. T., S. C. Herndon, E. Wood, T. B. Onasch, M. J. Northway, J. T. Jayne, M. R. Canagaratna, R. C. Miake-Lye and W. Berk Knighton (manuscript in prepartion, 2008). "Gas Turbine Engine Emissions Part 1. Hydrocarbons and Nitrogen Oxides" Aerodyne Research, Inc., Billerica, MA.

Timko, M. T., T. B. Onasch, M. J. Northway, J. T. Jayne, M. R. Canagaratna, S. C. Herndon, E. Wood and R. C. Miake-Lye (manuscript in prepartion, 2008). "Gas Turbine Engine Emissions Part 2. Chemical Properties of Particulate Matter" Aerodyne Research, Inc., Billerica, MA.

URS and FAA (2003). Select resource materials and annotated bibliography on the topic of hazardous air pollutants (HAPs) associated with aircraft, airports and aviation. Technical Directive Memorandum: D01-010, CSSI Contract: DTFA 01-99-Y-01002.

Wey, C. C. (2004). Overview of the Aircraft Particle Emissions eXperiment (APEX) Program. Aircraft Particle Emissions Workshop, Cleveland, OH.

Vay, S.A., B.E. Anderson, G. W. Sachse, J. E. Collins, Jr., J. R. Podolske, C. H. Twohy, B. Gandrud, K. R. Chan, S. L. Baughcum, H. A. Wallio. (1998) DC-8-based observations of aircraft CO, CH_4, N_2O, and $H_2O_{(g)}$ emission indices during SUCCESS. Geophysical Research Letters 25 1717-1720.

Wey, C. C., B. E. Anderson, et al. (2006). "Aircraft Particle Emissions eXperiment (APEX)." NASA/TM-2006-214382 **ARL-TR-3903**.

Wiesen, P. J., J. Kleffmann, R. Kurtenbach, K.H. Becker. (1994) Nitrous Oxide and Methane Emissions form Aero Engines. Geophysical Research Letters 21 2027-2030.

Wilkins, J. (2007). Description of the 2005 Boston Logan Airport Environmental Data Report. S. Herndon. Boston: LTO times compiled from actual data collected at the airport during 2005.

Yelvington, P. E., S. C. Herndon, J. C. Wormhoudt, J. T. Jayne, R. C. Miake-Lye, W. B. Knighton and C. C. Wey (2007). "Chemical Speciation of Hydrocarbon Emissions from a Commercial Aircraft Engine." Journal of Propulsion and Power **23**: 912-918.

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Aircraft Engine Speciated Organic Gases: Speciation Profile Spreadsheet

R.C. Miake-Lye

Introduction: A numerical spreadsheet[9] was developed that used both the Spicer data and APEX data to formulate a speciated profile of HC emissions, as discussed in the main body of this report. These several pages that follow are a description of the process used to develop that spreadsheet and an explanation of how the equations are used to provide the resulting calculated quantities. The spreadsheet (in Microsoft Excel format) is intended to accompany this documentation, with its data and imbedded equations.

The initial formulation of the spreadsheet was based on the several data sources (Spicer, and APEX, including both ARI/MSU and EPA contributions). These data sources are listed in columns, with the rows representing the numerous species measured by the several investigators. These data are combined to provide a single profile, as described more fully in the main body of the report. Below, the approach for that combination will be described.

After the profile was finalized, with many new species added and a few adjustments of specific species values from the original Spicer speciation, several additional quantities were calculated. The calculations are all imbedded in the spreadsheet, via the equations used to generate the quantities in the labeled cells, and the rationale behind the calculations will be presented below. The types of calculations are primarily directed at understanding how the speciated profile relates to the total amount of HCs emitted, which requires some assumptions since no measurement can quantify with complete certainty all of the HC emissions. As part of developing that understanding, calculations were also made to address questions of 1) how the limited measurements (such as that from a Flame Ionization Detector or FID, as used in certification testing) can be corrected to approximate the full HC complement and 2) how to convert HC emissions expressed in terms of methane mass equivalents, the reporting convention for HC EIs measured with a FID, into an estimate of the actual total mass of the full speciation profile, including unmeasured species. These calculations are all described below, as well.

An abbreviated version of the speciation spreadsheet is reproduced in Table 4 below. Species that have no mass fraction that are included in the spreadsheet for completeness are not included in Table 4. Also, the only columns from the spreadsheet that are shown in Table 4 are the profile species with non-zero mass fractions, their molecular mass and formula numbers, and the profile mass fraction. In the last two rows of Table 4, the fractions of the total profile mass represented by the identified species (71%) and that represented by the unidentified mass (29%) are listed, based on the total mass estimates given by Spicer and refined with the new measurements, and supported by the EPA

[9] The accompanying Microsoft Excel filename is **FAA-EPA_TSD_Speciated_HC_Aircraft_04AUG08.xls** and all references to columns, rows, or cells can be found in the worksheet titled "**Data Summary**".

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APEX data as discussed in the main report. The approach for calculating these quantities is discussed below.

Table 4. Aircraft Profile Speciation

Species	Molecular Weight	Formula			Mass Fraction
		C	H	O	
Ethylene	28	2	4		0.15459
Acetylene	26	2	2		0.03939
Ethane	30	2	6		0.00521
Propylene	42	3	6		0.04534
Propane	44	3	8		0.00078
Isobutene/1-Butene	56	4	8		0.01754
1,3-Butadiene	54	4	6		0.01687
cis-2-Butene	56	4	8		0.00210
3-Methyl-1-butene	70	5	10		0.00112
1-Pentene	70	5	10		0.00776
2-Methyl-1-butene	70	5	10		0.00140
n-Pentane	72	5	12		0.00198
trans-2-Pentene	70	5	10		0.00359
cis-2-Pentene	70	5	10		0.00276
2-Methyl-2-butene	70	5	10		0.00185
4-Methyl-1-pentene	84	6	12		0.00069
2-Methylpentane	86	6	14		0.00408
2-Methyl-1-pentene	84	6	12		0.00034
1-Hexene	84	6	12		0.00736
trans-2-Hexene	84	6	12		0.00030
Benzene	78	6	6		0.01681
1-Heptene	98	7	14		0.00438
n-Heptane	100	7	16		0.00064
Toluene	92	7	8		0.00642
1-Octene	112	8	16		0.00276
n-Octane	114	8	18		0.00062
Ethylbenzene	106	8	10		0.00174
m-Xylene/p-Xylene	106	8	10		0.00282
Styrene	104	8	8		0.00309
o-Xylene	106	8	10		0.00166
1-Nonene	126	9	18		0.00246
n-Nonane	128	9	20		0.00062
Isopropylbenzene	120	9	12		0.00003
n-Propylbenzene	120	9	12		0.00053
m-Ethyltoluene	120	9	12		0.00154
p-Ethyltoluene	120	9	12		0.00064
1,3,5-Trimethylbenzene	120	9	12		0.00054
o-Ethyltoluene	120	9	12		0.00065
1,2,4-Trimethylbenzene	120	9	12		0.00350
1-Decene	140	10	20		0.00185
n-Decane	142	10	22		0.00320
1,2,3-Trimethylbenzene	120	9	12		0.00106
n-Undecane	156	11	24		0.00444
n-Dodecane	170	12	26		0.00462
n-Tridecane	184	13	28		0.00535

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C14-alkane	198	14	30		0.00186
C15-alkane	212	15	32		0.00177
n-tetradecane	198	14	30		0.00416
C16-alkane	226	16	34		0.00146
n-pentadecane	212	15	32		0.00173
n-hexadecane	226	16	34		0.00049
C18-alkane	254	18	38		0.00002
n-heptadecane	240	17	36		0.00009
phenol	94	6	6	1	0.00726
naphthalene	128	10	8		0.00541
2-methyl naphthalene	142	11	10		0.00206
1-methyl naphthalene	142	11	10		0.00247
dimethylnapthalenes	156	12	12		0.00090
C4-Benzene + C3-aroald	134	10	14		0.00656
C5-Benzene+C4-aroald	148	11	16		0.00324
Methanol	32	1	4	1	0.01805
Formaldehyde (FAD)	30	1	2	1	0.12308
Acetaldehyde (AAD)	44	2	4	1	0.04272
Acetone	58	3	6	1	0.00369
Propionaldehyde	58	3	6	1	0.00727
Crotonaldehyde	70	4	6	1	0.01033
Butyraldehyde	72	4	8	1	0.00119
Benzaldehyde	106	7	6	1	0.00470
Isovaleraldehyde	86	5	10	1	0.00032
Valeraldehyde	86	5	10	1	0.00245
o-Tolualdehyde	120	8	8	1	0.00230
m-Tolualdehyde	120	8	8	1	0.00278
p-Tolualdehyde	120	8	8	1	0.00048
Methacrolein	70	4	6	1	0.00429
Glyoxal	58	2	2	2	0.01816
Methylglyoxal	72	3	4	2	0.01503
acrolein	56	3	4	1	0.02449
Sum of all identified species					**0.70787**
Unidentified mass					**0.29213**

Development of the Profile: As described in the main report, most of the species contributions measured by Spicer were supported by the APEX measurements. So, the data columns in the spreadsheet (not included in Table 4 above) show values for each measured species, in separate columns for each data source. If the data from APEX were not significantly different from Spicer's, the value from Spicer's column was used. This was true for almost all of the species measured by Spicer. The two exceptions were phenol and butyraldehyde (also called butanal). In these two cases, the more recent APEX data were used to update the values for those species. Then, additional species from either the ARI/MSU team (color coded blue in the spreadsheet) or from EPA (yellow) were also added to the species list and their contributions quantified. All of these quantifications are first entered into the spreadsheet as column L as ratios of emission indices of the species in question to the emission index of formaldehyde. Column L is titled "Revised Ratios" since these are the EI ratios of the individual species to formaldehyde accounting for both Spicer and the more recent APEX data.

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Mass Fractions of Identified and Unidentified Species: Since the ratios of EIs are really mass ratios (EIs are mass ratios of the species to mass fuel burn, so ratioing EIs divides one EI by another and the fuel burn divides out), this column is a set of species:formaldehyde mass ratios. This is not useful for general application, since formaldehyde emissions are not generally measured or known. To be most generally useful, a profile for the full complement of species was desired. This could be done for the identified species, but there may be some HC species which contribute to the mass but which could not be identified.

In order to attempt to account for all of the HC species, including those not identified, Spicer's data was reviewed. Spicer attempted to do a complete carbon balance, based on the suite of instruments employed and accounting for corrections for sensitivities. With the set of species measured by Spicer, an estimate was made for the mass of the identified species and for those that were not identified. For the present purposes, we have taken Spicer's values to be correct for the unidentified species based on his measurements. We have also compared to the time-integrated LTO cycle HC data taken by EPA, which were taken under a different set of measurement protocols (integrating over power settings, including engine start, and the corresponding different effects of backgrounds) and have determined that the APEX EPA data is largely consistent with the Spicer data set (see main report).

So Spicer's unidentified mass fraction was taken as a starting point. However, the additional species included in APEX actually reduced this unidentified list and unidentified mass. And the adjustments of phenol and butyraldehyde must also be accounted for. So, in calculating column K of the spreadsheet (reproduced for non-zero mass fraction species in Table 4 above), the original species in Spicer's profile were summed (see cell K7 in the spreadsheet). In the equation in cell K7, the phenol and butyraldehyde values were individually reset to Spicer's original values rather than use the new "Revised Ratio" values in column L, and the sum was set to Spicer's original identified mass fraction so that Spicer's carbon balance could be used, albeit with the unidentified mass reduced due to the newly added species. (Note that Spicer quotes his numbers in terms of parts per million carbon (ppmC) concentrations. However, within the limits of accuracy of these calculations, the fractions of ppmC reported for identified and unidentified are equivalent to the masses identified and unidentified in that the mass/carbon for the two fractions, identified and unidentified, is not significantly different for these two fractions.)

With the sum calculated and set equal to the Spicer's identified mass fraction, the individual mass ratios in column L can be scaled such that they can be referenced to a total given by Spicer's carbon balance. Cell K7 of the spreadsheet takes the sum and uses Spicer's identified mass fraction, to give a scaling factor for each identified species in the "Revised Ratios" column (L) to give the resulting profile in column K. Because more species are now identified, the sum of the identified profile now comes to 70.8% of the total HC mass (cell K119). The new additions to the list represent 6.4 of the total HC mass (cell K120), while phenol and butyraldehyde adjust things a little as well from

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Spicer's original identified mass. The unidentified mass represents 29.2% of the total mass in this new profile (K126).

Determining Effective Mass of Total Profile and Corrections for FID response: Since certification data from commercial engines are available, such data are often used for estimating HC emissions. Unfortunately, there are two problems with that certification data. The measurement device prescribed for this measurement uses a FID, which essentially "counts carbon atoms". This raises two problems. One is that the FID does not count carbon atoms that have an oxygen atom attached, and so is not equally sensitive to all HC species. Second, since the measurement is "counting carbons", it keeps track of a concentration and there is no direct indication of the mass of the species in question. (Mass is determined by the amount of hydrogen and oxygen in the molecule in addition to the number of carbons.) For the certification numbers, a mass/carbon based on the methane molecule (molecular mass 16.04) is used by convention. This is purely an assumption and has not been based on measurements to date, as far as the authors know.

These two problems can be addressed with the detailed profile provided in column K. For the known species, the mass/carbon can be calculated, since both the number of carbons and the molecular mass are known (given in Table 4 above and in spreadsheet columns D and H, as well as hydrogen and oxygen numbers provided in columns I and J). From the individual mass/carbon numbers and the mass fractions in column K, the mass-weighted mass/carbon can be calculated for the identified profile. In order to correct the mass for the total profile, one would need to have the mass-weighted mass/carbon for the complete profile. Since we do not have the molecular masses and formulas for the unidentified species (because they are unidentified), that calculation cannot be done rigorously. Thus, an estimate of the mass/carbon for the full profile is required.

In order to estimate the mass/carbon for the full profile, the mass/carbon was examined for two classes of species in the identified species. The first class represents those species present at greater than 1% of the total HC mass in column K. This includes many light oxygenated HCs, which have a large oxygen contribution to their total mass. The mass/carbon for these light species is not likely to be similar to those larger HC in the unidentified mass contributions. These light species have a mass/carbon of 17.6 (cell C130). The remaining species in the identified list have a mass/carbon of 14.4 (cell C132), which is likely closer to what might be expected for the larger, partially oxidized species in the unidentified component. Any deviation from 14.4 for the unidentified, while not expected to be large, is also devalued by the modest (29%) contribution of the unidentified to the total. This argument indicates that a good estimate for the mass/carbon for the full profile can be calculated using this approach. Thus, assigning 14.4 to the unidentified and combining with the identified, gives a total mass/carbon for the full profile of 15.97 (cell C137). (This is surprisingly close to the original convention of using methane's molecular mass of 16.04.)

The problem of the FID's lack of sensitivity to carbons bound to oxygen can also be rectified by the profile information. By a similar approach to calculating the mass-weighted mass/carbon, the mass-weighted C/H/O ratios for the various profile

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components discussed above can be calculated. These are included in cells EFG130, EFG132, and EFG137. By ratioing to carbon, in cells EFG131, EFG133, and EFG138, the number of oxygens/carbon can be determined. Since each carbon effectively cancels out the measurement of one carbon by the FID, the FID response for the full profile can be estimated by subtracting cell G138 from cell E138 (or 1.00 – 0.1365). The FID response is then 0.8635 of the total carbon number, or the correction for the FID's lack of sensitivity due to oxygen containing molecules is 1.16 times the FID output.

To summarize:

To correct for the FID response to account for the oxygen content, multiply the FID measurement by 1.16.

To make use of the best estimate of the actual molecular masses of the HC species instead of using the equivalent methane convention, multiply the FID measurement by 15.97/16.04 = 0.996.

The net total correction is 1.16 times 0.996 = 1.16.

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APPENDIX 2

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6th International Conference
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ELECTRICAL CONDUCTIVITY OF HITTS ADDITIVE PACKAGES FOR THE JP8+100 PROGRAMME

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ABSTRACT

The behaviour of two HITTS high temperature additive packages has been studied to examine possible interference with existing conductivity improver and also to assess their potential as conductivity improvers. The HITTS additives are shown to impart sufficient conductivity to fuels to meet certain fuel conductivity specifications without the addition of Stadis. Use of the HITTS additives with Stadis is shown to produce values of conductivity above the fuel specification. The conductivity performance of the HITTS additives is unaffected by the presence of phenolic or sodium salt impurities in the fuel which have been shown to have a detrimental effect on the performance of Stadis. The conductivity behaviour of the individual components of the HITTS additives is discussed. The dispersant is the main conducting component in the additive packages, but there are variations in the magnitude of the conductivity observed.

1. INTRODUCTION AND AIMS

The major objective of the JP8+100 programme is to improve the thermal stability of jet fuel using carefully selected additives. However, in this paper we examine the effects of such additives on properties which are unrelated to thermal stability characteristics, but which can have important consequences for the handling characteristics of the fuel.

In earlier papers[1,2,3] we examined the effects of a wide range of compounds, representative of naturally-occurring fuel components, on the performance of static dissipators (conductivity improvers). The work identified highly polar species capable of substantially reducing their effectiveness.

Certain HITTS packages are known to impart some conductivity to fuel. This work investigates the magnitude of this conductivity effect, on a model fuel and on three real fuels, for two Betz JP8+100 additives based on SPEC-AID 8Q405. SPEC-AID 8Q405, alone, at a concentration of

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100mgl^{-1}, has been reported to produce an average conductivity increase of ~140pSm^{-1} in three reference fuels[4]. The spread of values in these fuels was not stated. The two fully formulated HITTS packages NB 345 S286 and SPEC-AID 8Q460 have been examined and components of the packages have been studied separately to identify components contributing to the conductivity.

The sensitivity of these HITTS packages to model impurities, phenols and sodium salts,has been determined and is compared with that of Stadis450. The effects of the HITTS additives on Stadis450 have also been measured.

Brief comments are made on the potential for the use of such additives as conductivity improvers.

2. EXPERIMENTAL

2.1 Materials: The composition of the HITTS additive packages NB 345 S286 and SPEC-AID 8Q460 are given in Table 1. The fully-formulated additives , SPEC-AID 8Q460 and NB234 S286A, the partially formulated package SPEC-AID8Q406 and the components SPEC-AID 8Q405(dispersant batch-1) and SPEC-AID8Q400(Betz metal deactivator) were supplied directly via Wright Patterson AFB by Betz Process Chemicals Inc. A second sample of SPEC-AID 8Q405 (batch-2), was supplied via British Petroleum. The additive BHT (2,6-diter-butyl-4-methyl phenol) was obtained from Aldrich Chemical Co Ltd., "conventional" metal deactivator (NN disalicylidene 1,2-propane diamine - abbreviated to c-MDA) from Pfalz and Bauer Inc., m-cresol from British Drug Houses and octylamine from Fluka Chemica.

Stocks of the HITTs fuels were held by and supplied to us by Shell. These were, an additive-free Merox base fuel (Merox-AF), having a kinematic viscosity of 3.698 mm^{2}s^{-1} at -20C, and two fuels produced from this to JetA1 and JP8 specification. These are designated Jet A1-MA1, which contains 1.87mgl^{-1} reformulated Stadis450 and JP8-MA2 which contains 1.87mgl^{-1} reformulated Stadis450 plus AL-48 to give a concentration of 1300mgl^{-1} of FSII and 27mgl^{-1}of Nalco 5403. The sources and purification procedures employed for materials used previously, have been described[1,2,3].

2.2 Equipment and measurements: All measurements were made with the apparatus described previously[2,3] and made at 25C. The series of measurement was as follows:

i) time dependence of conductivity for NB 345 S286 and SPEC-AID8Q460 in dodecane.

ii) the conductivity of NB 345 S286 and SPEC-AID 8Q460 in dodecane and HITTS Fuels over

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a concentration range of 10 mgl^{-1} to 800 mgl^{-1}.

iii) the conductivity of NB 345 S286 and SPEC-AID 8Q460, over a range 10mgl^{-1} to 800mgl^{-1}, in dodecane containing 3mgl^{-1} Stadis450

iv) *m*-cresol and 2,6-di-*tert*-butyl-4-methylphenol were added separately over the concentration range 50-1000 mgl^{-1} to solutions of 135mgl^{-1} NB 345 5286 in dodecane and HITTS Fuels and 127mgl^{-1} SPEC-AID 8Q460 in dodecane and HITTS Fuels. The conductivity was measured after each addition of the phenol.

v) sodium naphthenate was added, over the concentration range 0.3 to 18 mgl^{-1}, to solutions of 135mgl^{-1} NB 345 S286 in dodecane and 127mgl^{-1} SPEC-AID 8Q460 in dodecane. Conductivity measurements were made after each addition of sodium naphthenate.

vi) components of the additive packages namely SPEC-AID8Q405, SPEC-AID8Q400 and c-MDA were added separately to HITTS Fuels and the conductivity measured.

vii) test of the variability of samples of SPEC-AID8Q405 dispersant between batches (where impurity levels could be different) by measurement of the conductivity of batch 2 SPEC-AID,8Q405 in the three HITTS fuels to compare with similar results from batch 1.

viii) neutralisation of possible acidic impurities using SPEC-AID 8Q406 (SPEC-AID8Q405 + BHT antioxidant) was shaken for five minutes with finely divided $CaCO_3$ diluted with hexane, then separated and the solvent removed by evaporation. A control sample was treated in a similar way but without the $CaCO_3$.

Acid and Base Additions: In a preliminary attempt to investigate ion production mechanisms we have examined the effects of an amine and an acid on the conducting species. Octylamine, diluted in toluene, was added to a solution of 100mgl^{-1}dispersant SPEC-AID 8Q405 in the Merox-AF and the conductivity was measured after each addition. Similar measurements were made using dodecylbenzenesulphonic acid.

3. RESULTS AND DISCUSSION

3.1 The Time dependence of the Conductivity of Fully-Formulated Additives, NB345 S286 and SPEC-AID8Q460 in Dodecane Solutions

The time dependence of conductivity has been examined in a limited series of measurements over a three-hour period. These measurements were required in order to see if any large drifts in conductivity occurred during the time-scale of the experiments. The conductivity of the NB345 S286 solution(135mgl^{-1}) increases slowly with time whereas that for SPEC-AID8Q460 (127mgl^{-1})

shows a slow decrease. However in neither case were the changes sufficient to warrant detailed corrections to data obtained during the period of the experiments-normally about an hour.

3.2 Effect of Concentration of Fully-Formulated Additives on the Conductivity of Dodecane Solutions

Data in dodecane were required to provide a baseline for comparison with behaviour in real fuels. In these experiments only the the fully-formulated HITTS additive packages SPEC-AID 8Q460 and NB345 S286 were examined.

Figure 1 shows the effect of these packages on dodecane and demonstrates their ability to impart conductivity. We note also that the conductivity varies approximately linearly with concentration of the additive package, with the NB345 S286 giving a larger gradient than SPEC-AID8Q460. The recommended in-fuel concentrations of these additives are 135mgl^{-1} for the former and 127mgl^{-1} for the latter .

The behaviour of these packages in dodecane containing 3mgl^{-1} of original Stadis450 is shown in figure 2. The results of repeat runs, undertaken after an interval of nineteen months show a measurable change in behaviour. The fact that the stadis450/dodecane solution had a conductivity close to that in the original experiments suggests that the observed changes are due to ageing effects in the Hitts additives. The cause of the low concentration behaviour is not yet clear, however at concentrations >200mgl^{-1} the variation of conductivity with concentration for each package is similar to that observed in the absence of Stadis450. These low concentration effects are reminiscient of the effects of salts on Stadis450.

3.3 Effects of Polar Fuel Components on the Conductivity of Hitts Additives in Dodecane

Figure 3 shows the influence of m-cresol concentration on the conductivity of solutions containing given concentrations of (i) original-Stadis450, (ii) NB345 S286 and (iii) SPEC-AID8Q460. The concentrations chosen are recorded on the figures and correspond approximately to those used in jet fuels.

We previously reported on the influence of m-cresol on original-Stadis450[3] and this is also further discussed in an accompanying paper[5]. For SPEC-AID8Q460 we observe a small decrease in conductivity with concentration which is probably insignificant from a user viewpoint. For NB345 S286 conductivity appears to increase gradually with m-cresol concentration and the increase, after allowance for a small time correction, would be ~ 30pSm^{-1} at 1000mgl^{-1} m-cresol. For comparison figure 4 shows the effects of a highly hindered phenol of the type employed as

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antioxidants. This is a good example of an almost complete lack of any antagonistic interaction with any of the three additives.

Earlier results on the effects sodium salts of a naphthenic acid, a phenol and dodecylbenzenesulphonic acid, on the behaviour of original-Stadis450, showed strong antagonistic effects on conductivity response[3] and these were qualitatively similar for all three types of salt. Sodium naphthenate was chosen as representative of these and its influence on the additive packages is shown in figure 5. For each HITTS package the concentration dependence of conductivity is quite different from that of Stadis solutions. There is no minimum, the conductivity remains approximately constant up to a concentration of ~ $2mgl^{-1}$ and then increases with concentration. We note that sodium naphthenate alone imparts some conductivity[3], but this cannot account for the total observed increase. However, in this case, because the concentration of such compounds in fuels is likely to be low-probably $<1mgl^{-1}$, the practical effect of this will be very small.

3.4 Effects of Fully-Formulated Additives on the Conductivity of Hitts Fuels

We note that the conductivities of Jet A1-M1A and JP8-M2A, measured at the start of the study, are very similar, having values of ~ 500 pSm^{-1}. However , during the period of the work conductivity is seen to decrease for each fuel, with that for JP8 showing a fall of ~34% and for JetA1 a fall of ~20% over 250 days. This is taken into account in our comparisons of behaviour. The only difference between these fuel solutions is the presence of AL-48 in JP8-M2A. We know that in short-duration experiments AL-48 has no measurable effect on the performance of Stadis450[6]. No long-duration experiments ie up to ~250 days have yet been done.

Figure 6 shows the response of HITTs fuels to NB345 S286. This is represented by the increase in conductivity over the initial conductivity of the fuel. Dodecane data are shown for comparison. Clearly there are differences in response which follow the order : JP8 > Jet A1 > Merox-AF > Dodecane. Likewise figure 7 shows the response of HITTs fuels to SPEC-AID8Q460. In this case the differences in response are much less clear cut, though JP8 and Jet A1 again show greater resonse than Merox-AF and Dodecane. ie JetA1 ~ JP8 > Dodecane ~ Merox-AF. The lower viscosity for Merox-AF($1.45mm^2s^{-1}$) compared with dodecane($1.86mm^2s^{-1}$) at 25C would lead us to expect a higher conductivity in Merox-AF. Mixtures of aromatic and alkane liquids of a given viscosity are expected to promote a higher conductivity than an isoviscous pure alkane at the same temperature. Therefore the presence of aromatic components in Merox-AF(19%) will

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raise the conductivity[6]. To these effects must also be added those due to interactions between additives. The net result on ion production is seen in the measured conductivity. Paradoxically the low concentration behaviour observed with these additivesin Stadis/dodecane mixtures is not observed in the more complex real fuel systems. In these cases however, the ageing effect has not yet been examined.

A practical point is that, at the recommended dosing concentration for HITTs additives in JP8 and JetA1, the total conductivities, as shown in table 2, are above the upper limit specification values of 600pSm^{-1} and 450 pSm^{-1} respectively. We also note that the conductivity of Merox-AF, containing the recommended concentrations *is* within the specification conductivity range for JetA1 without the addition of Stadis 450, but 8Q460 falls slightly short of the minimum value for JP8. However we feel that more data is required on batch-to-batch variations and on fuel composition effects.

3.5 Effect of Model Phenolic Impurities on the Conductivity of HITTS Additives in HITTS Fuels

Figure 8 shows that the total measured conductivities of SPEC-AID 8Q460 in Merox-AF are *insensitive* to the presence of *m*-cresol "impurities". Results for NB345 S286 are similar. The apparent sensitivity to *m*-cresol in the JP8 and JETA1 fuels can therefore be attributed to the interaction of the *m*-cresol with the Stadis450 in these fuels and not to any interaction of the *m*-cresol with NB 345 S286 or SPEC-AID8Q460.

3.6 Effects of Additive Components on the Conductivity of HITTS Fuels

Work on a range of phenol types[5] in dodecane has shown that highly hindered phenols have little or no effect on the conductivity of hydrocarbons nor do they adversely affect the performance of Stadis450. We have confirmed that BHT does not contribute to the conductivity of the additive package in any of the HITTS fuels.

Earlier measurements on conventional-MDA in dodecane showed it had no effect on conductivity[1] Figure 9 shows that this is also true for solutions in Merox-AF and JP8. For Jet A1 a small decrease of ~10% is observed in the concentration range 0 to 100 mgl^{-1}.

In marked contrast, the Betz MDA, see figure 10, although it contributes only a small amount to the conductivity of Merox-AF, nevertheless has a considerable enhancing effect on the conductivity of Jet A1 and causes a modest reduction in the conductivity of JP8. These effects are clearly indicative of interaction between this MDA and components present in these fuels.

Repeat runs with this additive, after an ageing period of eighteen months, demonstrated an increased response. However, during this period the USAF decided not to consider a new MDA but to continue with conventional MDA. For this reason work on Betz MDA was discontinued. Figure 11 shows that the dispersant SPEC-AID8Q405 imparts significant conductivity to each of the fuels and conductivity varies linearly with concentration above ~50mgl^{-1}. We note the response follows the order JP8 > Jet A1 > Merox-AF as observed for the fully-formulated additive packages. In view of the results for BHT and c-MDA discussed above, it is clear that SPEC-AID8Q405 is the only conducting component in SPEC-AID8Q460 and is the main, but not the sole conducting component in NB345 S286.

3.7 Effect of Batch Variation on the Behaviour of SPEC-AID 8Q405

Figure 11, also demonstates batch to batch variation on the conductivity-improving ability of SPEC-AID 8Q405 with Batch 2 giving generally lower conductivity values. At a concentration of 100mgl^{-1}, batch-1 in Merox-AF meets the Jet-A1 and JP8 conductivity specifications, without Stadis, whereas batch-2 meets that for Jet-A1 only. Either batch added to Jet-A1 fuel causes the conductivity to be out of specification. This is also the case for addition of batch-1 to JP8 fuel. The magnitudes of some of the observed effects seems also to be influenced by ageing of the fuels and we hope to examine this further.

3.8 Preliminary Investigation of the Conducting Species

The conductivities of both carbonate-treated and untreated SPEC-AID8Q406 samples (see para 2.2) are identical. This suggests that participation of acidic species in the conduction process is unlikely.

Figure 12 shows that both dodecylbenzenesulphonic acid n-octylamine interact to increase the conductivity. Repeat experiments after an interval of sixteen months show, that apart from some small apparent differences at very low concentrations, the behaviour is generally unchanged within the experimental uncertainty. In the case of the sulphonic acid the effect is partly due to the acid itself[1,3]. However, this cannot be the explanation for the effect of the amine which alone has no effect on the conductivity[6]. More information is required before much speculation can be justified.

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4. SUMMARY AND CONCLUSIONS

4.1 CONDUCTIVITY BEHAVIOUR OF HITTS PACKAGES

4.1.1 In Model Fuel (Dodecane) with Model Impurities

1 Both the HITTS packages impart conductivity which shows a small time dependence.

2 Both the HITTS packages can impart conductivity to fuel, without the use of Stadis450.

3 The conductivity response of both the HITTS packages is insensitive to phenolic impurities.

4 The conductivity response of both the HITTS packages is insensitive to sodium salts.

5 The HITTS packages have the advantage of imparting the required conductivity to fuels without the sensitivity to fuel impurities, such as phenols and sodium salts, which is detrimental to Stadis450.

4.1.2 In HITTS Fuels

1 Both the HITTS additive packages used at the recommended concentration in the HITTS fuels JP8 MA2 and JETA1 M1A, gave conductivities *above* the fuel specification.

2 The conductivity of the MeroxA-F containing the recommended levels of both HITTS packages was within the fuel conductivity specification for Jet-A1 *without* the use of Stadis450. For JP8 with the additive 8Q460, conductivity falls slightly short of the minimum conductivity specification

3 There is a simple linear relationship between conductivity and the concentration of the HITTS additives.

4 Both the HITTS additive packages appear to be unaffected by the presence of phenolic impurities in fuel.

5 Reduction in conductivity in the HITTS JP8 and JET A1 with the HITTS additives in the presence of phenolic impurities is attributed to interaction of the phenol with the Stadis 450 in these fuels.

6 The HITTS additives show potential as conductivity improvers. Additional work is required on batch-to batch variation, ageing effects and on the temperature dependence of conductivity before these additives can be given serious consideration as sole conductivity improvers.

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4.2 CONDUCTIVITY BEHAVIOUR OF *INDIVIDUAL COMPONENTS* OF HITTS ADDITIVES

1 The c-MDA contributes little to the conductivity of the HITTS additive.

2 The contribution of the Betz MDA to conductivity is complex. In the Merox-AF the Betz MDA contributes a small increment to the conductivity. In the JP8 it produced a reduction in conductivity and in the JETA1 it produced an increase in conductivity. The reasons for the variations could be due to interaction with Stadis450 and/or water in the fuels. Recently the Betz MDA has ceased to be of interest to USAF.

3 The BHT antioxidant does not contribute to the conductivity of the HITTS additives.

4 The dispersant SPEC-AID8Q405 is the main conducting component in the HITTS additives. At 100mgl^{-1} in the presence of Stadis, conductivity will generally exceed the specification upper limit. In the absence of Stadis it is likely that the Jet-A1 specification will be met but there is uncertainty with respect to JP8.

5. ACKNOWLEDGEMENTS

The authors wish to thank additive manufacturers and oil companies, in particular BP, for their constructive cooperation and for supplies of additives and fuels. Especially they would like to thank BP and DRA for many helpful and enjoyable discussions during the course of this work. They also wish to express their thanks to the DRA for its funding support provided under DRA Contract LSF/E 20093.

6. REFERENCES

1.Dacre,B.; Abi Aoun, W.G. The Effects of Fuel Components on the Behaviour of Conductivity Improvers in Jet Fuel, 4th International Conference on Stability and Handling of Liquid Fuels, Orlando, Florida,USA, November 1991.

2.Dacre,B.; Abi Aoun, W.G. Effects of Fuel Components on the Performance of Conductivity Improvers in Hydrocarbons, Journal of Electrostatics,39(1997)89-110.

3.Dacre,B.; Hetherington, J.I. Behaviour of Conductivity Improvers in Jet Fuel, 5th International

II, 11

Conference on Stability and Handling of Liquid Fuels, Rotterdam, The Netherlands, October 1994.

4.Anderson, S.D.; Harrison,W.E.; Edwards,T.; Morris,R.W.; Shouse,D.T. Development of Thermal Stability Additive Packages for JP-8, 5th International Conference on Stability and Handling of Liquid Fuels, Rotterdam, The Netherlands, October 1994.

5.Dacre,B.; Hetherington, J.I. The Effect of Phenolic Impurities in Jet Fuel on the Behaviour of Conductivity Improvers, 6th International Conference on Stability and Handling of Liquid Fuels Vancouver, B. C., Canada, October 13-17, 1997 .

6.Dacre,B.; Hetherington, J.I. Preliminary unpublished work.

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Commercial Additive	Description	Concentration Added to Fuel	Comments
BHT	Antioxidant 2,6-di-*tert*-butyl-4-methylphenol	25mgl^{-1}	
MDA (conventional)	Metal Deactivator NN'disalicylidene-1,2-propanediamine	10mgl^{-1}	
8Q405	Dispersant BETZ (proprietory)	100mgl^{-1}	
Spec Aid 8Q400	Betz Metal Deactivator	10mgl^{-1}	Different chemistry from conventional DuPont MDA
Spec Aid 8Q406	8Q405 / BHT dispersant / antioxidant	125mgl^{-1}	
NB 345 S286A	Experimental 8Q405/BHT/8Q400 Dispersant / Antioxidant / Betz MDA	135mgl^{-1}	Assumed composition: 8Q405 100mgl^{-1} BHT 25mgl^{-1} MDA 10mgl^{-1} (Betz)
Spec Aid 8Q460	8Q405 / BHT /MDA Dispersant / Antioxidant / MDA (conventional chemistry)	127mgl^{-1}	Assumed composition: 8Q405 100mgl^{-1} BHT 25mgl^{-1} MDA 2mgl^{-1} (conventional)

Table 1 Composition of HITTS High Temperature Additive Packages

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FUELS	SPEC AID8Q460 127mgl^{-1}	NB 345 S286 135mgl^{-1}
Merox-AF	123	221
Jet-A1	666	817
JP8	668	864
Dodecane	132	200

Values taken from data in figures 7 and 8.

Specification Conductivity ranges: Jet-A1 50--450pSm^{-1}
JP8 150--600pSm^{-1}

Table 2 Measured Conductivities (pSm^{-1}) in HITTS Fuels

Fuel	Batch-1 100mgl^{-1}	Batch-2 100mgl^{-1}
Merox-AF	158	115
Jet-A1	689	584
JP8	671	557

Values taken from data in figure 11.

Table 3 Measured Conductivities (pSm^{-1}) of 8Q405 in HITTS Fuels

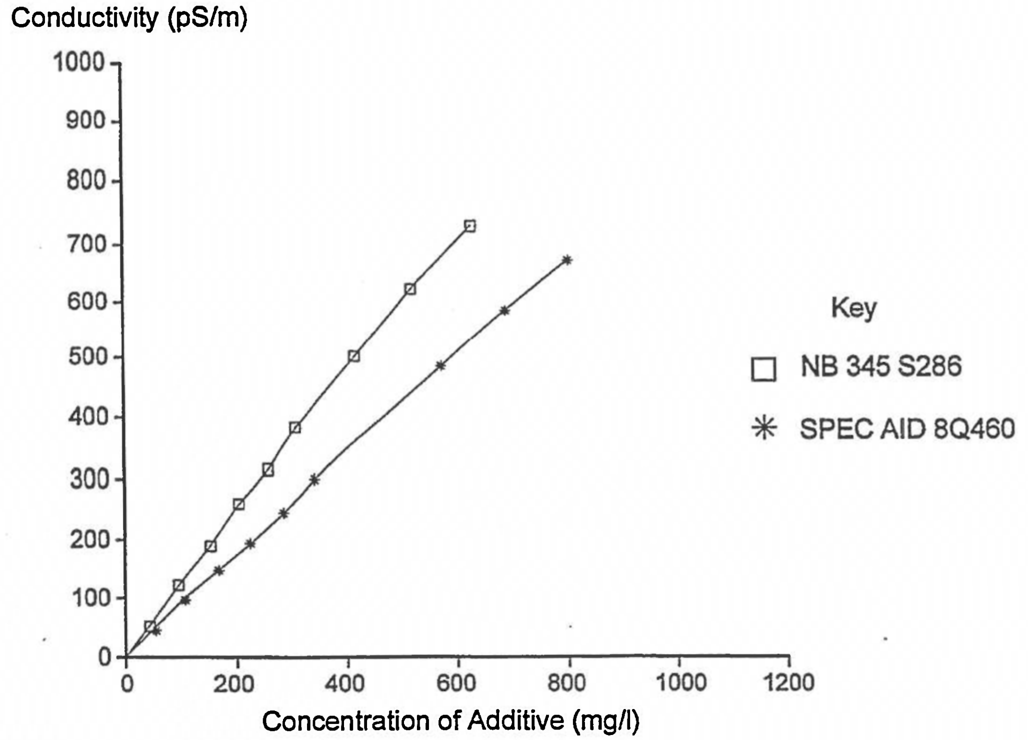

Fig. 1 Conductivity vs. Concentration for High Temperature Additive Packages in Dodecane

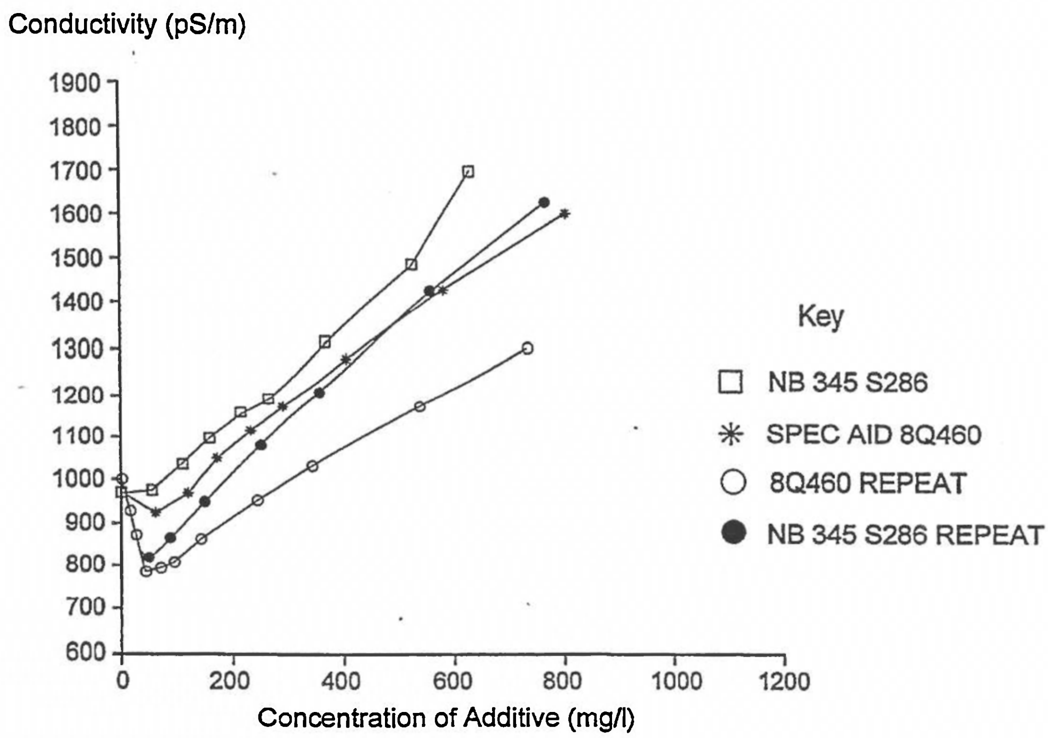

Fig. 2 Effect of High Temperature Additive Packages on Conductivity of 3mg/l STADIS 450 in Dodecane

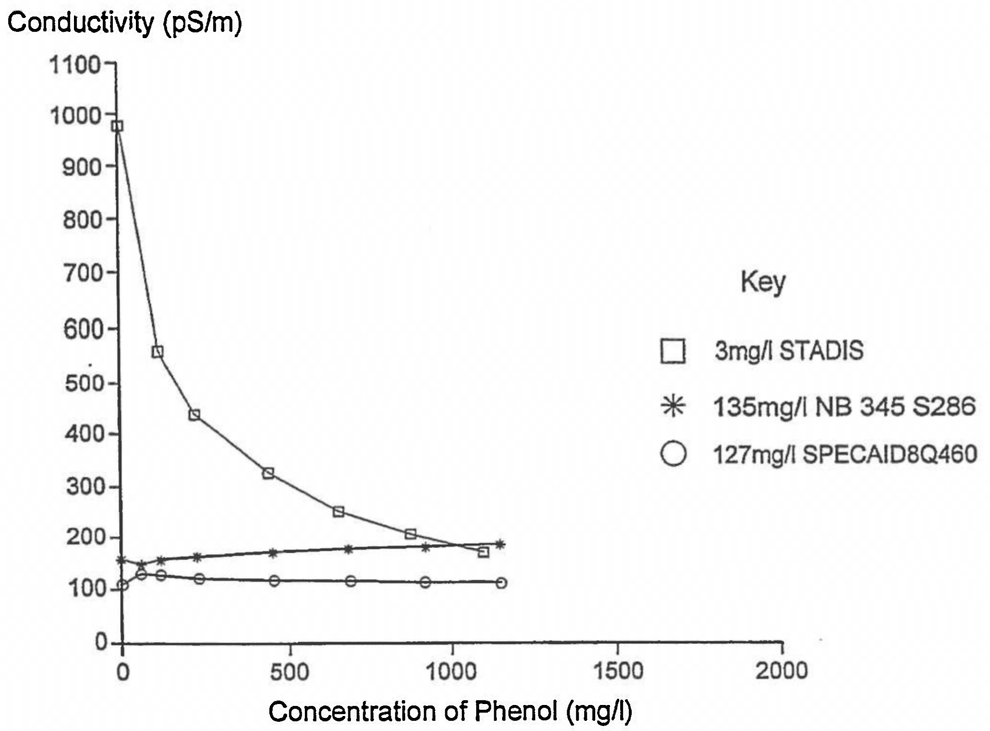

Fig. 3 ffect of m-Cresol on Conductivity of Stadis 450 and High Temperature Additive Packages in Dodecane

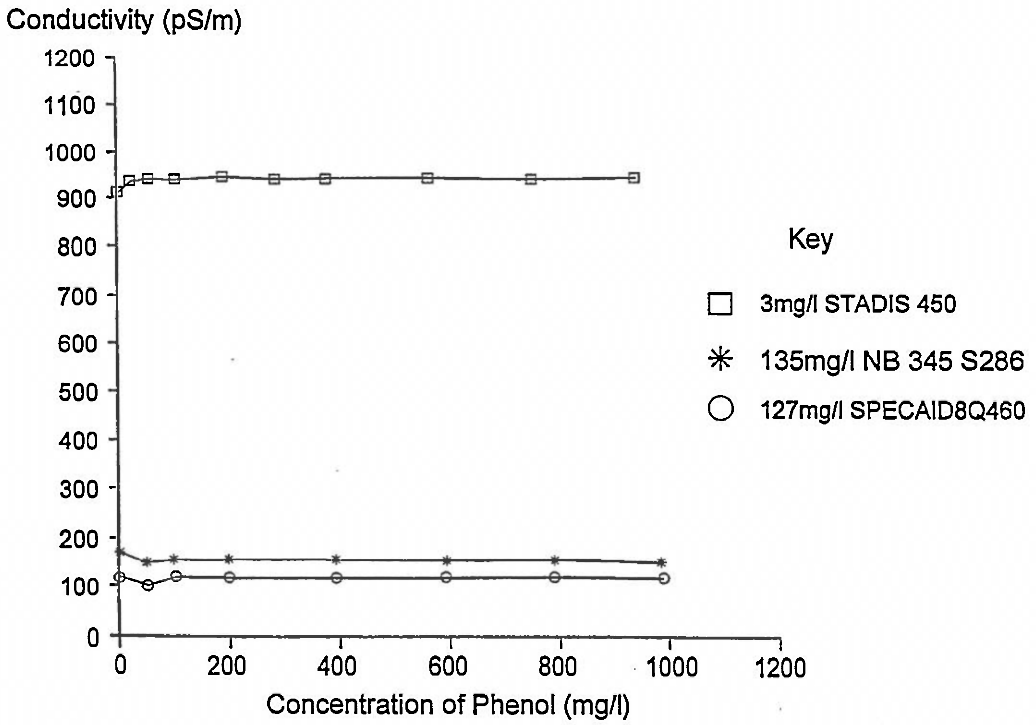

Fig. 4 Effect of 2,6di(tert)butyl-4-methylphenol on Conductivity of Stadis 450 and High Temperature Additive Packages in Dodecane

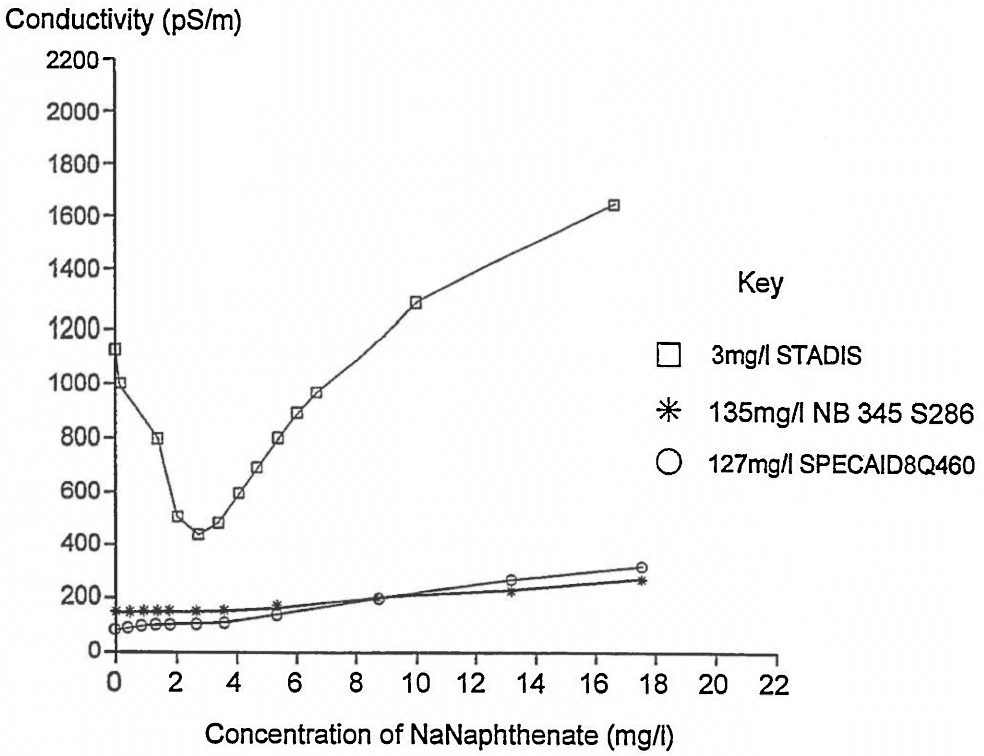

Fig. 5 Effect of Sodium Naphthenate on Conductivity of Stadis 450 and High Temperature Additive Packages in Dodecane

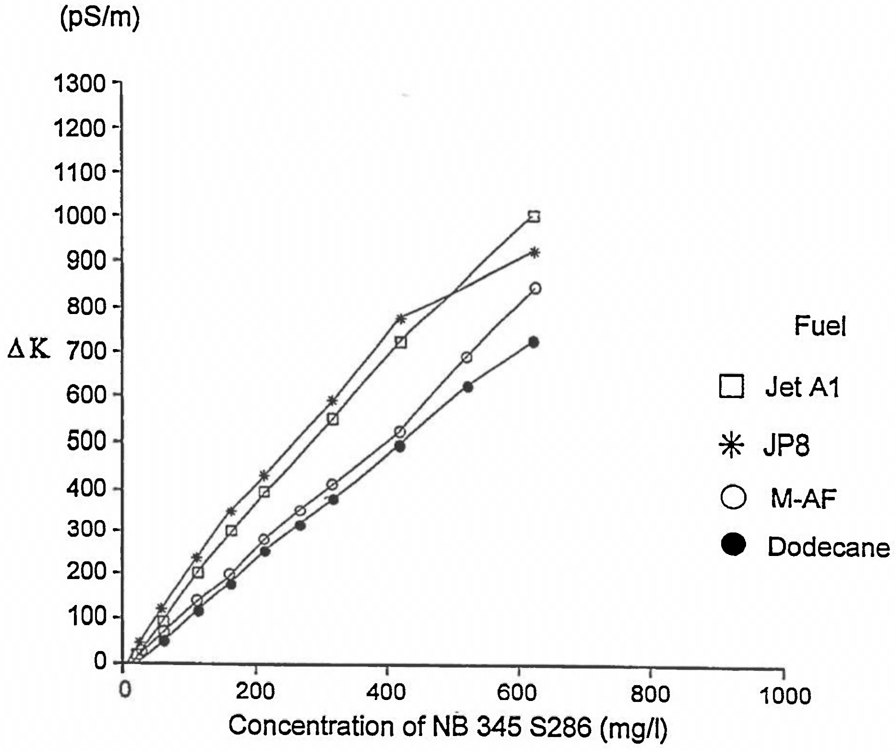

Fig. 6 Effect of NB 345 S286 on the Conductivity of HITTS Fuels

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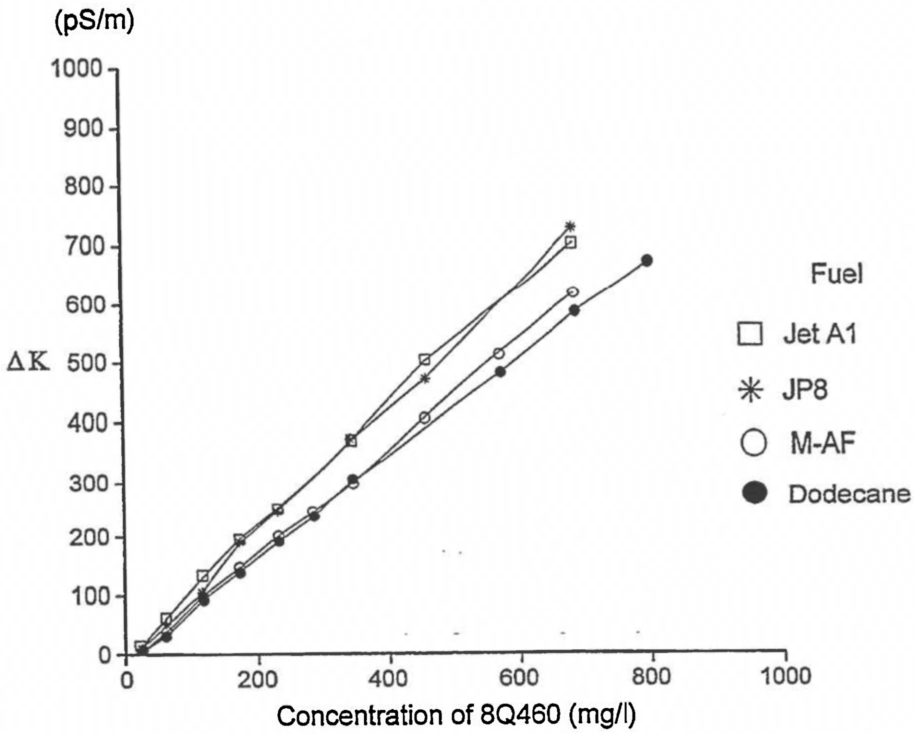

Fig. 7 Effect of 8Q460 on the Conductivity of HITTS Fuels

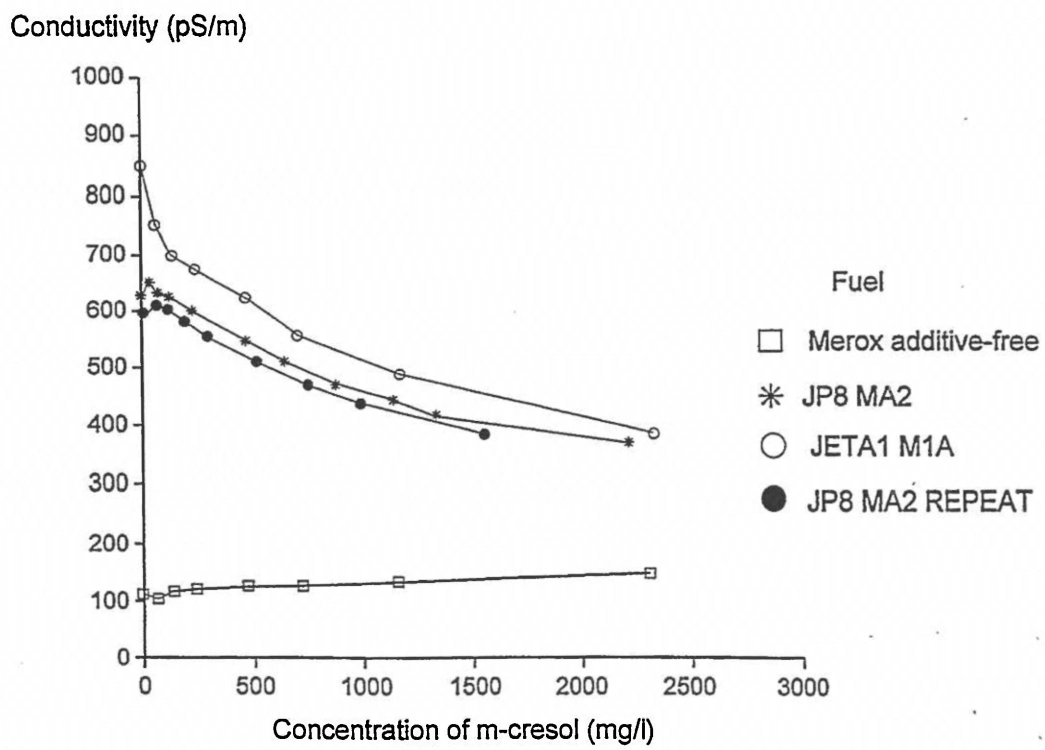

Fig. 8 Effect of m-cresol on Conductivity of 127 mg/l SPECAID 8Q460 in HITTS Fuels

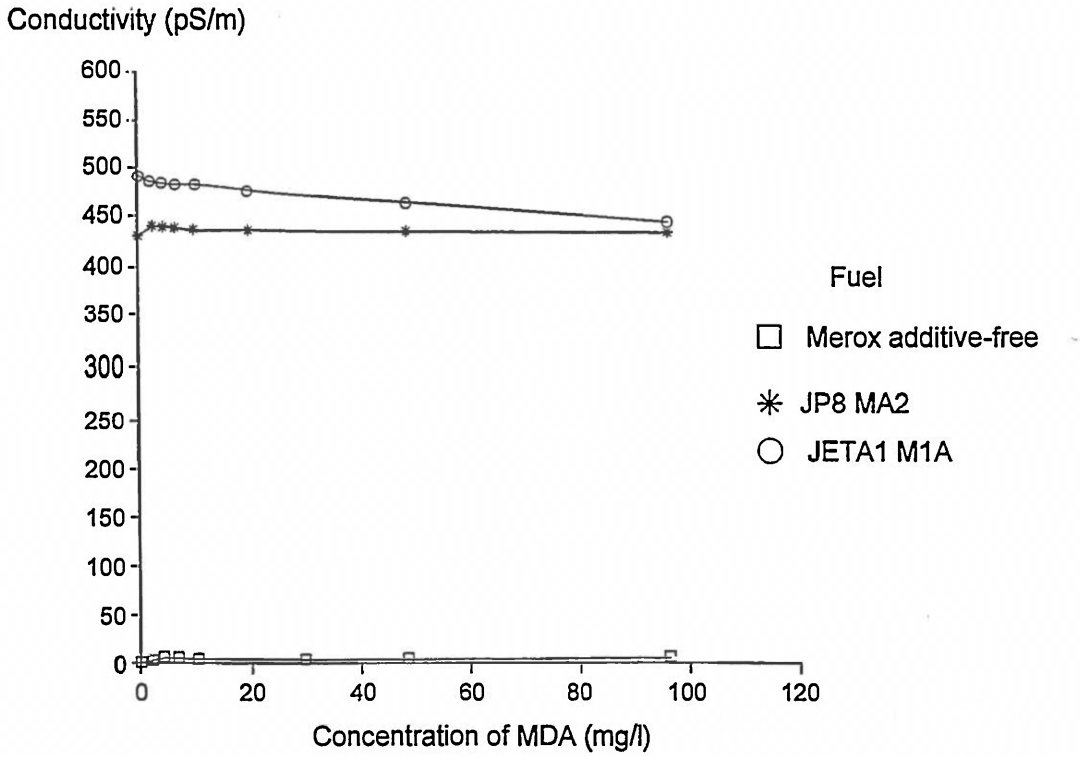

Fig. 9 Effect of MDA (conventional) on Conductivity of HITTS Fuels

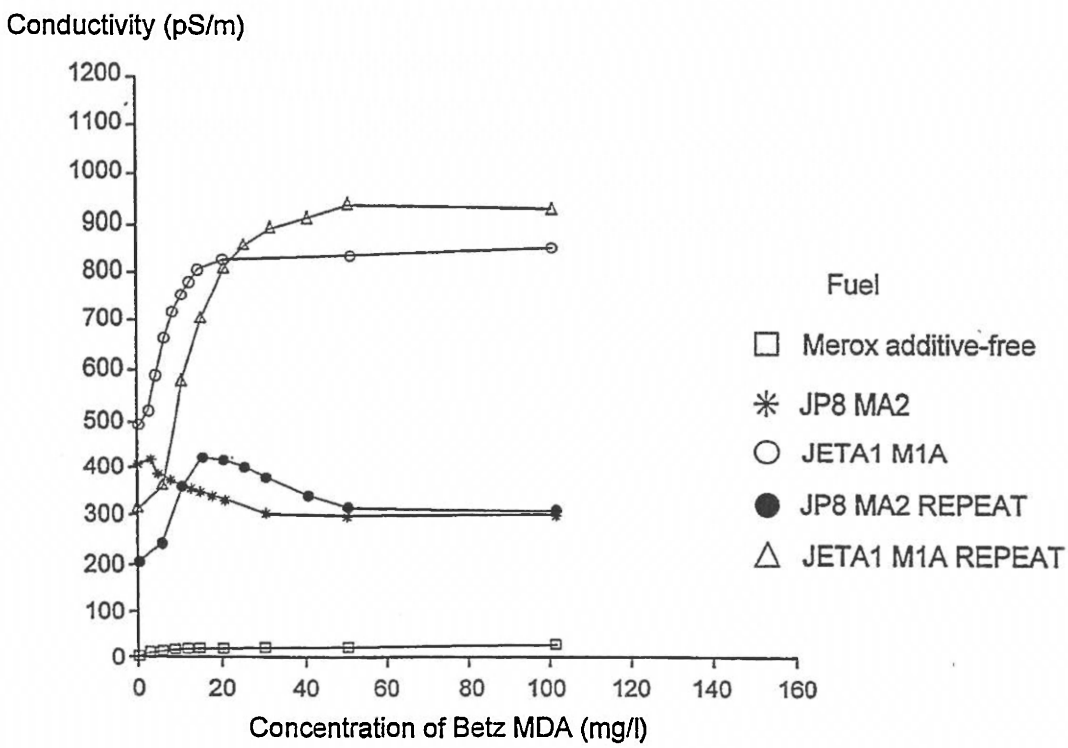

Fig. 10 Effect of Betz MDA on Conductivity of HITTS Fuels

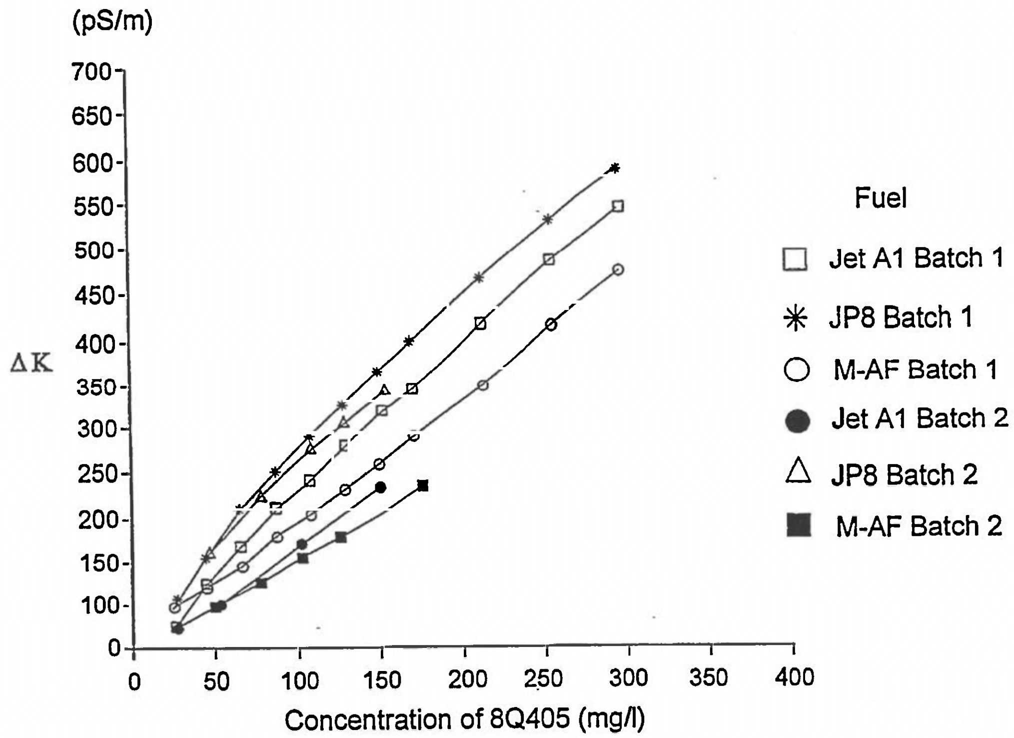

Fig. 11 Effect of 8Q405 and Batch Variation on the Conductivity of HITTS Fuels

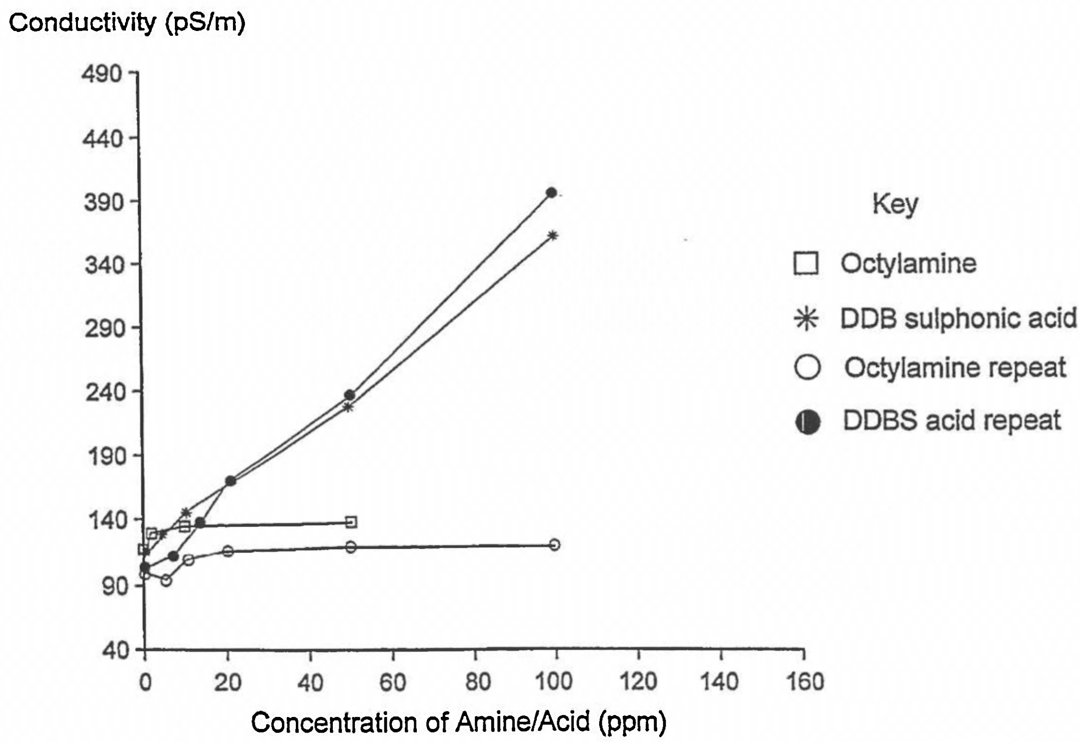

Fig. 12 Betz Dispersant 8Q405(Batch 2) 100mg/l in HITTS Additive-free Merox
Effect of Acid or Amine on Conductivity

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METRIC

MIL-DTL-83133F
11 April 2008

SUPERSEDING
MIL-DTL-83133E
1 April 1999

DETAIL SPECIFICATION

TURBINE FUEL, AVIATION, KEROSENE TYPE, JP-8 (NATO F-34), NATO F-35, and JP-8+100 (NATO F-37)

This specification is approved for use by all Departments and Agencies of the Department of Defense.

Comments, suggestions, or questions on this document should be addressed to HQ AFPET/AFTT, 2430 C Street, Bldg 70, Area B, Wright-Patterson AFB OH 45433-7632 or e-mailed to AFPET.AFTT@wpafb.af.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at http://assist.daps.dla.mil.

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1. SCOPE

1.1 Scope. This specification covers three grades of kerosene type aviation turbine fuel, JP-8 (NATO F-34), NATO F-35, and JP-8+100 (NATO F-37). This specification was thoroughly reviewed as a part of acquisition reform. While most of the requirements were converted to performance terms, not all requirements could be converted due to the military-unique nature of the product (see 6.1) and the need for compatibility with deployed systems. The issuance of this specification as "detail" is not intended to constrain technology advances in future systems.

1.2 Classification. Aviation turbine fuel will be of the following grades, as specified (see 6.2).

Grade	NATO Code No.	Description
JP-8	F-34	Kerosene type turbine fuel which will contain a static dissipator additive, corrosion inhibitor/lubricity improver, and fuel system icing inhibitor, and may contain antioxidant and metal deactivator.
	F-35	Kerosene type turbine fuel which will contain a static dissipator additive, may contain antioxidant, corrosion inhibitor/lubricity improver, and metal deactivator but will not contain fuel system icing inhibitor.
JP-8+100	F-37	JP-8 type kerosene turbine fuel which contains thermal stability improver additive (NATO S-1749) as described in 3.3.6.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, or 5 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this specification, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-DTL-5624	Turbine Fuel, Aviation, Grades JP-4 and JP-5
MIL-PRF-25017	Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble
MIL-DTL-85470	Inhibitor, Icing, Fuel System, High Flash NATO Code Number S-1745

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DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-290	Packaging of Petroleum and Related Products

QUALIFIED PRODUCTS LIST

QPL-25017	Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble

(Copies of these documents are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia PA 19111-5094 or online at http://assist.daps.dla.mil)

2.3 Non-government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

ASTM International

ASTM D 56	Standard Test Method for Flash Point by Tag Closed Cup Tester (DoD Adopted)
ASTM D 86	Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure (DoD Adopted)
ASTM D 93	Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester (DoD Adopted)
ASTM D 129	Standard Test Method for Sulfur in Petroleum Products (General Bomb Method) (DoD Adopted)
ASTM D 130	Standard Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test (DoD Adopted)
ASTM D 156	Standard Test Method for Saybolt Color of Petroleum Products (Saybolt Chromometer Method) (DoD Adopted)
ASTM D 381	Standard Test Method for Gum Content in Fuels by Jet Evaporation (DoD Adopted)
ASTM D 445	Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity) (DoD Adopted)
ASTM D 976	Standard Test Methods for Calculated Cetane Index of Distillate Fuels (DoD Adopted)
ASTM D 1094	Standard Test Method for Water Reaction of Aviation Fuels (DoD Adopted)
ASTM D 1266	Standard Test Method for Sulfur in Petroleum Products (Lamp Method) (DoD Adopted)
ASTM D 1298	Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method (DoD Adopted)
ASTM D 1319	Standard Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption (DoD Adopted)
ASTM D 1322	Standard Test Method for Smoke Point of Kerosine and Aviation Turbine Fuels (DoD Adopted)
ASTM D 1840	Standard Test Method for Naphthalene Hydrocarbons in Aviation

	Turbine Fuels by Ultraviolet Spectrophotometry (DoD Adopted)
ASTM D 2276	Standard Test Method for Particulate Contaminant in Aviation Fuel by Line Sampling (DoD Adopted)
ASTM D 2386	Standard Test Method for Freezing Point of Aviation Fuels (DoD Adopted)
ASTM D 2622	Standard Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-Ray Fluorescence Spectrometry (DoD Adopted)
ASTM D 2624	Standard Test Methods for Electrical Conductivity of Aviation and Distillate Fuels (DoD Adopted)
ASTM D 2887	Standard Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography (DoD Adopted)
ASTM D 3120	Standard Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry (DoD Adopted)
ASTM D 3227	Standard Test Method for (Thiol Mercaptan) Sulfur in Gasoline, Kerosine, Aviation Turbine, and Distillate Fuels (Potentiometric Method) (DoD Adopted)
ASTM D 3241	Standard Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels (JFTOT Procedure) (DoD Adopted)
ASTM D 3242	Standard Test Method for Acidity in Aviation Turbine Fuel (DoD Adopted)
ASTM D 3338	Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuels (DoD Adopted)
ASTM D 3343	Standard Test Method for Estimation of Hydrogen Content of Aviation Fuels (DoD Adopted)
ASTM D 3701	Standard Test Method for Hydrogen Content of Aviation Turbine Fuels by Low Resolution Nuclear Magnetic Resonance Spectrometry (DoD Adopted)
ASTM D 3828	Standard Test Methods For Flash Point by Small Scale Closed Cup Tester (DoD Adopted)
ASTM D 3948	Standard Test Method for Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable Separometer (DoD Adopted)
ASTM D 4052	Standard Test Method for Density and Relative Density of Liquids by Digital Density Meter (DoD Adopted)
ASTM D 4057	Standard Practice for Manual Sampling of Petroleum and Petroleum Products (DoD Adopted)
ASTM D 4177	Standard Practice for Automatic Sampling of Petroleum and Petroleum Products (DoD Adopted)
ASTM D 4294	Standard Test Method for Sulfur in Petroleum and Petroleum Products by Energy-Dispersive X-Ray Fluorescence Spectrometry (DoD Adopted)
ASTM D 4306	Standard Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination (DoD Adopted)
ASTM D 4529	Standard Test Method for Estimation of Net Heat of Combustion of Aviation Fuels
ASTM D 4737	Standard Test Method for Calculated Cetane Index by Four Variable Equation

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ASTM D 4809	Standard Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method) (DoD Adopted)
ASTM D 4952	Standard Test Method for Qualitative Analysis for Active Sulfur Species in Fuels and Solvents (Doctor Test) (DoD Adopted)
ASTM D 5001	Standard Test Method for Measurement of Lubricity of Aviation Turbine Fuels by the Ball-on-Cylinder Lubricity Evaluator (BOCLE)
ASTM D 5006	Standard Test Method for Measurement of Fuel System Icing Inhibitors (Ether Type) in Aviation Fuels (DoD Adopted)
ASTM D 5186	Standard Test Method for Determination of the Aromatic Content and Polynuclear Aromatic Content of Diesel Fuels and Aviation Turbine Fuels by Supercritical Fluid Chromatography
ASTM D 5452	Standard Test Method for Particulate Contamination in Aviation Fuels by Laboratory Filtration (DoD Adopted)
ASTM D 5453	Standard Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence
ASTM D 5972	Standard Test Method for Freezing Point of Aviation Fuels (Automatic Phase Transition Method)
ASTM D 6045	Standard Test Method for Color of Petroleum Products by the Automatic Tristimulus Method
ASTM D 7153	Standard Test Method for Freezing Point of Aviation Fuels (Automatic Laser Method)
ASTM D 7154	Standard Test Method for Freezing Point of Aviation Fuels (Automatic Fiber Optical Method)
ASTM D 7224	Standard Test Method for Determining Water Separation Characteristics of Kerosine-type Aviation Turbine Fuels Containing Additives by Portable Separometer
ASTM E 29	Standard Practice for Using Significant Digits in Test Data to Determine Conformance with the Specifications (DoD Adopted)
IEEE/ASTM SI 10	American National Standard for Use of the International System of Units (SI): The Modern Metric System (DoD Adopted)

(Copies of these documents are available at ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken PA 19428-2959. Electronic copies of ASTM standards may be obtained from http://www.astm.org)

2.4 Order of precedence. In the event of a conflict between the text of this document and the references cited herein (except for related specification sheets), the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Materials. Fuel supplied under this specification shall be refined hydrocarbon distillate fuel oils containing additives in accordance with 3.3. The feedstock from which the fuel is refined shall be crude oils derived from petroleum, tar sands, oil shale, or mixtures thereof.

3.1.1 Materials for Blending. With the approval of both the procuring activity and the applicable fuel technical authorities listed below, up to 50 volume % of the finished fuel may consist solely of Synthetic Paraffinic Kerosene (SPK) derived from a Fischer-Tropsch (FT) process meeting requirements of Appendix A. Finished fuel shall contain additives in accordance with 3.3. During the platform certification/approval process, JP-8 containing SPK will be designated JP-8/SPK.

Procuring Activity: Product Technology and Standardization, DESC, 8725 John J. Kingman Road, Fort Belvoir, VA 22060

Cognizant activity for the Navy and Marine Corps: Naval Fuels and Lubricants Cross Functional Team, AIR-4.4.1, Building 2360, 22229 Elmer Road, Patuxent River, MD 20670-1534.

Cognizant activity for the Air Force: Fuels Certification Office, 77th Monohan Street, Area B, Wright-Patterson AFB, OH 45433-7017.

Cognizant activities for the Army:

Army Ground: US Army TARDEC/RDECOM, 6501 E. 11 Mile Road, AMSRD-TAR-D (MS-110), Warren, MI 48397-5000.

Army Aviation: US Army RDECOM, Attn: AMSRD-AMR-AE-P, Building 4488, Room C-211, Redstone Arsenal, AL 35898-5000

3.1.2 Non-FT Materials. The use of synthetic blending materials represents a potential departure from experience and from the key assumptions which form the basis for fuel property requirements. It is the long-term goal of this specification to fully encompass fuels derived from synthetic materials and non-conventional sources once they have been defined but, this is only partially complete. Until this is accomplished, specific fuel formulations from synthetic materials or non-conventional sources may be submitted to AFRL/RZTG, Bldg 490, 1790 Loop Road N, WPAFB, OH 45433 to begin evaluation of compliance with the intent of this specification.

3.2 Chemical and physical requirements. The chemical and physical properties of a finished fuel containing only the materials described in 3.1 shall conform to the requirements listed in Table 1.

3.2.1 Chemical and physical requirements of blended finished fuels. The chemical and physical properties of a finished fuel blend containing any amount of synthetic SPK as described in 3.1.1 shall conform to the requirements listed in Table 2.

3.3 Additives. The type and amount of each additive used shall be made available when requested by the procuring activity or user (6.2.d). The only additives approved for use are those referenced in this specification.

3.3.1 Antioxidants. Immediately after processing and before the fuel is exposed to the atmosphere (such as during rundown into feed/batch tankage), an approved antioxidant (3.3.1.1) shall be blended into the fuel in order to prevent the formation of gums and peroxides after manufacture. The concentration of the antioxidant to be added shall be:

a. Not less than 17.2 milligrams (mg) nor more than 24.0 mg of active ingredient per liter (L) of fuel (6.0 to 8.4 lb/1000 barrels) to all JP-8 fuel that contains blending stocks that have been hydrogen treated or were manufactured from a Fischer-Tropsch process.

b. At the option of the supplier, not more than 24.0 mg of active ingredient per liter of fuel (8.4 lb/1000 barrels) may be added to JP-8 fuels that do not contain hydrogen treated blending stocks nor Fischer-Tropsch products.

3.3.1.1 Antioxidant formulations. The following antioxidant formulations are approved:

a. 2,6-di-tert-butyl-4-methylphenol

b. 6-tert-butyl-2,4-dimethylphenol

c. 2,6-di-tert-butylphenol

d. 75 percent min-2,6-di-tert-butylphenol
25 percent max tert-butylphenols and tri-tert-butylphenols

e. 72 percent min 6-tert-butyl-2,4-dimethylphenol
28 percent max tert-butyl-methylphenols and tert-butyl-dimethylphenols

f. 55 percent min 2,4-dimethyl-6-tert-butylphenol and
15 percent min 2,6-di-tert-butyl-4-methylphenol and
30 percent max mixed methyl and dimethyl tert-butylphenols

3.3.2 Metal deactivator. A metal deactivator, N,N'-disalycylidene-1,2-propanediamine, may be blended into the fuel. The concentration of active material used on initial batching of the fuel at the refinery shall not exceed 2.0 mg/L. Cumulative addition of metal deactivator when redoping the fuel, shall not exceed 5.7 mg/L. Metal deactivator additive shall not be used in JP-8 unless the supplier has obtained written consent from the procuring activity and user.

3.3.3 Static dissipater additive. An additive shall be blended into the fuel in sufficient concentration to increase the conductivity of the fuel at the point of injection to within the range specified in Table 1 for fuel offered in accordance with 3.1 or as specified in Table 2 for finished fuel when allowed per 3.1.1. The point of injection of the additive shall be determined by agreement between the purchasing authority and the supplier. The following electrical conductivity additive is approved: Stadis® 450 marketed by Innospec Fuel Specialties LLC (formerly Octel Starreon LLC), Newark, DE 19702.

3.3.4 Corrosion inhibitor/lubricity improver additive. A corrosion inhibitor/lubricity improver (CI/LI) additive conforming to MIL-PRF-25017 shall be blended into the F-34 (JP-8) grade fuel by the contractor. The CI/LI additive is optional for F-35. The amount added shall be equal to or greater than the minimum effective concentration and shall not exceed the maximum allowable concentration listed in the latest revision of QPL-25017. The contractor or transporting agency, or both, shall maintain and upon request shall make available to the Government evidence that the CI/LI additives used are equal in every respect to the qualification products listed in QPL-25017. The point of injection of the CI/LI additive shall be determined by agreement between the purchasing authority and the supplier.

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TABLE 1. <u>Chemical and physical requirements and test methods</u>.

Property	Min	Max	Test Methods ASTM Standards
Color, Saybolt [1]			D 156 [2] or D 6045
Total acid number, mg KOH/gm		0.015	D 3242
Aromatics, vol percent		25.0	D 1319
Sulfur, total, mass percent		0.30	D 129, D 1266, D 2622, D 3120, D 4294 [2], or D 5453
Sulfur mercaptan, mass percent or		0.002	D 3227
Doctor test		negative	D 4952
Distillation temperature, °C [3] (D 2887 limits given in parentheses)			D 86 [2] or D 2887
Initial boiling point [1]			
10 percent recovered		205 (186)	
20 percent recovered [1]			
50 percent recovered [1]			
90 percent recovered [1]			
Final boiling point		300 (330)	
Residue, vol percent		1.5	
Loss, vol percent		1.5	
Flash point, °C [4]	38		D 56, D 93 [2], or D 3828
Density			D 1298 or D 4052 [2]
Density, kg/L at 15°C or	0.775	0.840	
Gravity, API at 60°F	37.0	51.0	
Freezing point, °C		-47	D 2386 [2]. D 5972, D 7153, or D 7154
Viscosity, at -20°C, mm^2/s		8.0	D 445
Net heat of combustion, MJ/kg	42.8		D 3338, D 4529, or D 4809 [2]
Hydrogen content, mass percent	13.4		D 3343 or D 3701 [2]
Smoke point, mm, or	25.0		D 1322
Smoke point, mm, and	19.0		D 1322
Naphthalenes, vol percent		3.0	D 1840
Calculated cetane index [1]			D 976 [5] or D 4737
Copper strip corrosion, 2 hr at 100°C (212°F)		No. 1	D 130
Thermal stability			D 3241 [6]
change in pressure drop, mm Hg		25	
heater tube deposit, visual rating		<3 [7]	

TABLE 1. Chemical and physical requirements and test methods* – *Continued

Property	Min	Max	Test Methods ASTM Standards
Existent gum, mg/100 mL		7.0	D 381
Particulate matter, mg/L [8]		1.0	D 2276 or D 5452 [2]
Filtration time, minutes [8]		15	
Water reaction interface rating		1 b	D 1094
Water separation index [9]			D 3948 or D 7224 [2]
Fuel system icing inhibitor, vol percent	0.10	0.15	D 5006 [10]
Fuel electrical conductivity, pS/m [11]			D 2624

NOTES:

1. To be reported – not limited.
2. Referee Test Method.
3. A condenser temperature of 0° to 4°C (32° to 40°F) shall be used for the distillation by ASTM D 86.
4. ASTM D 56 may give results up to 1°C (2°F) below the ASTM D 93 results. ASTM D 3828 may give results up to 1.7°C (3°F) below the ASTM D 93 results. Method IP170 is also permitted.
5. Mid-boiling temperature may be obtained by either ASTM D 86 or ASTM D 2887 to perform the cetane index calculation. ASTM D 86 values should be corrected to standard barometric pressure.
6. See 4.5.3 for ASTM D 3241 test conditions and test limitations.
7. Peacock or Abnormal color deposits result in a failure.
8. A minimum sample size of 3.79 liters (1 gallon) shall be filtered. Filtration time will be determined in accordance with procedure in Appendix B. This procedure may also be used for the determination of particulate matter as an alternate to ASTM D 2276 or ASTM D 5452.
9. The minimum microseparometer rating using a Micro-Separometer (MSEP) shall be as follows:

JP-8 Additives	MSEP Rating, min.
Antioxidant (AO)*, Metal Deactivator (MDA)*	90
AO*, MDA*, and Fuel System Icing Inhibitor (FSII)	85
AO*, MDA*, and Corrosion Inhibitor/Lubricity Improver (CI/LI)	80
AO*, MDA*, FSII and CI/LI)	70

*Even though the presence or absence does not change these limits, samples submitted for specification or conformance testing shall contain the same additives present in the refinery batch. Regardless of which minimum the refiner selects to meet, the refiner shall report the MSEP rating on a laboratory hand blend of the fuel with all additives required by the specification.

10. Test shall be performed in accordance with ASTM D 5006 using the DiEGME scale of the refractometer.
11. The conductivity must be between 150 and 600 pS/m for F-34 (JP-8) and between 50 and 600 pS/m for F-35, at ambient temperature or 29.4°C (85°F), whichever is lower, unless otherwise directed by the procuring activity. In the case of JP-8+100, JP-8 with the thermal stability improver additive (see 3.3.6), the conductivity limit must be between 150 to 700 pS/m at ambient temperature or 29.4°C (85°F), whichever is lower, unless otherwise directed by the procuring activity.

TABLE 2. <u>Chemical and physical requirements and test methods for JP-8 with up to 50 percent SPK blend component</u>

Property	Min	Max	Test Methods ASTM Standards
Color, Saybolt [1]			D 156 [2] or D 6045
Total acid number, mg KOH/gm		0.015	D 3242
Aromatics, vol percent	8.0	25.0	D 1319
Olefins, vol percent		5.0	D 1319
Sulfur, total, mass percent		0.30	D 129, D 1266, D 2622, D 3120, D 4294 [2], or D 5453
Sulfur mercaptan, mass percent or		0.002	D 3227
Doctor test		negative	D 4952
Distillation temperature, °C [3]			D 86
Initial boiling point [1]			
10 percent recovered (T10)	157	205	
20 percent recovered [1]			
50 percent recovered (T50)	168	229	
90 percent recovered (T90)	183	262	
Final boiling point		300	
T50 – T10	15		
T90 – T10	40		
Residue, vol percent		1.5	
Loss, vol percent		1.5	
Flash point, °C [4]	38	68	D 56, D 93 [2], or D 3828
Density			D 1298 or D 4052 [2]
Density, kg/L at 15°C or	0.775	0.840	
Gravity, API at 60°F	37.0	51.0	
Freezing point, °C		-47	D 2386 [2], D 5972, D 7153, or D 7154
Viscosity, at -20°C, mm^2/s		8.0	D 445
Net heat of combustion, MJ/kg	42.8		D 3338, D 4529, or D 4809 [2]
Hydrogen content, mass percent	13.4		D 3343 or D 3701 [2]
Smoke point, mm, or	25.0		D 1322
Smoke point, mm, and	19.0		D 1322
Naphthalenes, vol percent		3.0	D 1840
Calculated cetane index [1]			D 976 [5] or D 4737
Copper strip corrosion, 2 hr at 100°C (212°F)		No. 1	D 130
Thermal stability			D 3241 [6]
change in pressure drop, mm Hg		25	
heater tube deposit, visual rating		<3 [7]	

TABLE 2. Chemical and physical requirements and test methods for JP-8 with up to 50 percent SPK blend component – Continued

Property	Min	Max	Test Methods ASTM Standards
Existent gum, mg/100 mL Particulate matter, mg/L [8] Filtration time, minutes [8] Water reaction interface rating Water separation index [9]		7.0 1.0 15 1 b	D 381 D 2276 or D 5452 [2] D 1094 D 3948 or D 7224 [2]
Fuel system icing inhibitor, vol percent	0.10	0.15	D 5006 [10]
Fuel electrical conductivity, pS/m [11]			D 2624
Lubricity, wear scar diameter, mm		0.85	D 5001

NOTES:
1. To be reported – not limited.
2. Referee Test Method.
3. A condenser temperature of 0° to 4°C (32° to 40°F) shall be used for the distillation by ASTM D 86.
4. ASTM D 56 may give results up to 1°C (2°F) below the ASTM D 93 results. ASTM D 3828 may give results up to 1.7°C (3°F) below the ASTM D 93 results. Method IP170 is also permitted.
5. Mid-boiling temperature may be obtained by ASTM D 86 to perform the cetane index calculation. ASTM D 86 values should be corrected to standard barometric pressure.
6. See 4.5.3 for ASTM D 3241 test conditions and test limitations.
7. Peacock or Abnormal color deposits result in a failure.
8. A minimum sample size of 3.79 liters (1 gallon) shall be filtered. Filtration time will be determined in accordance with procedure in Appendix B. This procedure may also be used for the determination of particulate matter as an alternate to ASTM D 2276 or ASTM D 5452.
9. The minimum microseparometer rating using a Micro-Separometer (MSEP) shall be as follows:

JP-8 Additives	MSEP Rating, min.
Antioxidant (AO)*, Metal Deactivator (MDA)*	90
AO*, MDA*, and Fuel System Icing Inhibitor (FSII)	85
AO*, MDA*, and Corrosion Inhibitor/Lubricity Improver (CI/LI)	80
AO*, MDA*, FSII and CI/LI)	70

*Even though the presence or absence does not change these limits, samples submitted for specification or conformance testing shall contain the same additives present in the refinery batch. Regardless of which minimum the refiner selects to meet, the refiner shall report the MSEP rating on a laboratory hand blend of the fuel with all additives required by the specification.

10. Test shall be performed in accordance with ASTM D 5006 using the DiEGME scale of the refractometer.
11. The conductivity must be between 150 and 600 pS/m for F-34 (JP-8) and between 50 and 600 pS/m for F-35, at ambient temperature or 29.4°C (85°F), whichever is lower, unless otherwise directed by the procuring activity. In the case of JP-8+100, JP-8 with the thermal stability improver additive (see 3.3.6), the conductivity limit must be between 150 to 700 pS/m at ambient temperature or 29.4°C (85°F), whichever is lower, unless otherwise directed by the procuring activity.

3.3.5 Fuel system icing inhibitor. The use of a fuel system icing inhibitor shall be mandatory for JP-8 and shall conform to MIL-DTL-85470. The point of injection of the additive for JP-8 shall be determined by agreement between the purchasing authority and the supplier. The fuel system icing inhibitor is not to be added to NATO F-35 unless so directed by the purchasing authority.

3.3.6 Thermal stability improver additive. Due to logistic concerns, personnel at the operating location shall request written approval from the cognizant activity to add a thermal stability improver additive to the fuel. If approval is given, the concentration of the additive and location of injection shall be specified by the cognizant service activity listed below. For USAF aircraft, this approval does not override the single manager's authority for specifying allowed/disallowed fuels. JP-8 fuel with an approved thermal stability improver additive at the required concentration shall be designated as JP-8+100. Thermal stability improver additive shall not be used in JP-8 without approval, in writing, from:

Cognizant activity for the Navy and Marine Corps: Naval Fuels and Lubricants Cross Functional Team, AIR-4.4.1, Building 2360, 22229 Elmer Road, Patuxent River, MD 20670-1534.

Cognizant activity for the Air Force: HQ Air Force Petroleum Agency, HQ AFPET/AFT, 2430 C Street, Building 70, Area B, Wright-Patterson AFB 45433-7632.

Cognizant activities for the Army:

Army Ground: US Army TARDEC/RDECOM, 6501 E. 11 Mile Road, AMSRD-TAR-D (MS-110), Warren, MI 48397-5000.

Army Aviation: US Army RDECOM, Attn: AMSRD-AMR-AE-P, Building 4488, Room C-211, Redstone Arsenal, AL 35898-5000

3.3.6.1 Qualified additives. Qualified thermal stability improver additives are listed in Table 3.

TABLE 3. Qualified thermal stability improver additives.

Additive Name	Qualification Reference	Manufacturer
SPEC AID 8Q462	AFRL/PRSF Ltr, 9 Dec 97	GE Water & Process Technologies 9669 Grogan Mill Road The Woodlands, TX 77380
AeroShell Performance Additive 101	AFRL/PRSF Ltr, 13 Jan 98	Shell Aviation Limited Shell Centre York Road London, UK SE1 7NA

3.3.7 Premixing of additives. Additives shall not be premixed with other additives before injection into the fuel so as to prevent possible reactions among the concentrated forms of different additives.

3.4 Workmanship. At the time of Government acceptance, the finished fuel or finished fuel blend shall be visually free from undissolved water, sediment or suspended matter, and shall be clear and bright. In case of dispute, the fuel shall be clear and bright at 21°C (70°F) and shall contain no more than 1.0 mg/L of particulate matter as required in Table 1 for any finished fuel containing only the materials described in 3.1 or, Table 2 for finished fuel blends containing any amount of SPK as described in 3.1.1.

3.5 Recycled, recovered, or environmentally preferable materials. Recycled, recovered, or environmentally preferable materials should be used to the maximum extent possible, provided that the material meets or exceeds the operational and maintenance requirements, and promotes economically advantageous life cycle costs.

4. VERIFICATION

4.1 Classification of inspections. The inspection requirements specified herein are classified as quality conformance inspections (see 4.2).

4.2 Qualification inspection conditions. Test for acceptance of individual lots shall consist of tests for all applicable requirements specified in section 3. Quality conformance inspection shall include the test requirements herein.

. 4.2.1 Inspection lot. For acceptance purposes, individual lots shall be examined as specified herein and subjected to tests for all applicable requirements cited in section 3.

4.3 Inspection.

4.3.1 Inspection conditions. Any finished fuel containing only the materials described in 3.1 shall comply with the limiting values specified in Table 1 using the cited test methods. Any finished fuel blend containing any amount of SPK as described in 3.1.1 shall comply with the limiting values specified in Table 2 using the cited test methods. Any SPK blend component as described in 3.1.1 shall comply with the limiting values specified in Table A-I using the cited test methods. The specified limiting values must not be changed. This precludes any allowance for test method precision and adding or subtracting digits. For the purposes of determining conformance with the specified limiting values, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right hand place of digits used in expressing the specified limiting value, in accordance with the Rounding-Off Method of ASTM E 29.

4.4 Sampling plans.

4.4.1 Sampling. Each bulk or packaged lot of material shall be sampled for verification of product quality in accordance with ASTM D 4057 or ASTM D 4177, except where individual test procedures contain specific sampling instructions.

4.4.2 Sampling for inspection of filled containers. A random sample of filled containers shall be selected from each lot and shall be subjected to the examination of filled containers as specified in 4.5.1.3.

4.5 Methods of inspection.

4.5.1 Examination of product.

4.5.1.1 Visual inspection. Samples selected in accordance with 4.4.1 shall be visually examined for compliance with 3.4.

4.5.1.2 Examination of empty containers. Before filled, each unit container shall be visually inspected for cleanliness and suitability in accordance with ASTM D 4057.

4.5.1.3 Examination of filled containers. Samples taken as specified in 4.4.2 shall be examined for conformance to MIL-STD-290 with regard to fill, closure, sealing, leakage, packaging, packing, and markings. Any container with one or more defects under the required fill shall be rejected.

4.5.2 Chemical and physical tests. Tests to determine compliance with chemical and physical requirements shall be conducted in accordance with Table 1 or Table 2 and/or Table A-I as follows. Any finished fuel containing only the materials described in 3.1 shall pass all tests listed in Table 1. Any finished fuel containing any amount of SPK as described in 3.1.1 shall pass all tests listed in Table 2. Any SPK blend component as defined in 3.1.1 shall pass all tests listed in Table A-I. No additional testing shall be required. Requirements contained herein are not subject to corrections for test tolerances. If multiple determinations are made, results falling within any specified repeatability and reproducibility tolerances may be averaged. For rounding off of significant figures, ASTM E 29 shall apply to all tests required by this specification.

4.5.3 Thermal stability tests. The thermal stability test shall be conducted using ASTM D 3241. The heated tube shall be rated visually (see Annex A1 of ASTM D 3241).

4.5.3.1 ASTM D 3241 test conditions.

a. Heater tube temperature at maximum point: 260°C (500°F).

b. Fuel system pressure: 3.45 MPa (500 psig).

c. Fuel flow rate: 3.0 mL/min.

d. Test duration: 150 minutes.

4.5.3.2 ASTM D 3241 reported data. The following data shall be reported:

a. Differential pressure in millimeter of mercury at 150 minutes, or time to differential pressure of 25 mm Hg, whichever comes first.

b. Heater tube deposit visual code rating at the end of the test.

5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When actual packaging of materiel is to be performed by DoD or in-house contractor personnel, these personnel need to contact the responsible packaging activity to ascertain packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activities within the Military Service or Defense Agency, or within the military service's system commands. Packaging data retrieval is available from the managing Military Department's or Defense Agency's automated packaging files, CD-ROM products, or by contacting the responsible packaging activity.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. The fuels covered by this specification are intended for use in aircraft turbine engines. JP-8 contains military unique additives that are required by military weapon systems. This requirement is unique to military aircraft and engine designs. When authorized, JP-8 (F-34) may be used in ground - based turbine and diesel engines. NATO F-35 is intended for commercial aviation, but can be converted to JP-8 (F-34) by the addition of the appropriate additives.

6.2 Acquisition requirements. Acquisition documents must specify the following:

a. Title, number, date of this specification, and grade (type) of fuel.
b. Quantity required and size containers desired.
c. Level of packaging and packing required (see 5.1).
d. Location and injection method for addition of electrical conductivity additive, fuel system icing inhibitor and corrosion inhibitor, as required.

6.3 Conversion of metric units. Units of measure have been converted to the International System of Units (SI) (Metric) in accordance with ASTM SI 10. If test results are obtained in units other than metric or there is a requirement to report dual units, ASTM SI 10, should be used to convert the units.

6.4 Definitions.

6.4.1 Bulk lot. A bulk lot consists of an indefinite quantity of a homogeneous mixture of material offered for acceptance in a single isolated container or manufactured in a single plant run through the same processing equipment, with no change in ingredient material.

6.4.2 Packaged lot. A packaged lot consists of an indefinite number of 208-liter (55-gallon) drums, or smaller unit packages of identical size and type, offered for acceptance and filled from an isolated tank containing a homogeneous mixture of material; or filled with a homogeneous mixture of material run through the same processing equipment with no change in ingredient material.

6.4.3 Homogenous product. A homogeneous product is defined as a product where samples taken at various levels of the batch tank are tested for the defining homogeneous characteristics and all values obtained meet the repeatability precision requirements for that test method.

6.4.4 Synthetic Paraffinic Kerosene (SPK) Kerosene consisting solely of n-paraffins, cyclic-paraffins, and iso-paraffins.

6.4.5 Fischer-Tropsch (FT) Process A catalyzed chemical process in which a synthesis gas consisting of carbon monoxide and hydrogen are converted into liquid hydrocarbons of various forms. Typical catalysts used are based on iron and cobalt.

6.5 Subject term (key word) listing.

Antioxidants
Corrosion inhibitor
Fischer-Tropsch
Flash point
Freezing point
Hydrocarbon distillate fuel
Hydrogen content
Icing inhibitor
Synthetic Paraffinic Kerosene (SPK)
Lubricity improver
Static dissipator
Thermal stability improver

6.6 International agreements. Certain provisions of this specification are the subject of international standardization agreement ASIC AIR STD 15/6, ASIC AIR STD 15/9, NATO STANAG 1135, and NATO STANAG 3747. When amendment, revision, or cancellation of this specification is proposed which will modify the international agreement concerned, the preparing activity will take appropriate action through international standardization channels including departmental standardization offices, to change the agreement or make other appropriate accommodations.

6.7 Material safety data sheet. Contracting officers will identify those activities requiring copies of completed Material Safety Data Sheets prepared in accordance with FED-STD-313. The pertinent Government mailing addresses for submission of data are listed in FED-STD-313.

6.8 Test report. Test data required by 4.5 should be available for the procurement activity and user in the same order as listed in Table 1 for materials conforming to 3.2 requirements or as listed in Table 2 for materials conforming to 3.2.1 requirements. The Inspection Data on Aviation Turbine Fuels form published in ASTM D 1655 should be used as a guide. Also, the type and amount of additives used should be reported.

6.9 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

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SYNTHETIC PARAFFINIC KEROSENE (SPK)

A.1 SCOPE

A.1.1 Scope. This Appendix addresses 100 percent SPK derived from manufactured products of a Fischer-Tropsch process (identified in 3.1.1). This Appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

A.2 REQUIREMENTS

A.2.1 Chemical and physical requirements. The chemical and physical requirements of the SPK shall conform to those specified in Table A-I.

A.2.2 Additives.

A.2.2.1 Antioxidants. Addition of antioxidants shall adhere to the criteria specified in 3.3.1.

A.2.2.2 Static dissipater additive (SDA). If SPK is to be transported prior to blending with refined hydrocarbon distillate fuel, static dissipater additive shall be injected in sufficient concentration to increase the conductivity of the fuel to within the range specified in Table A-I. The point of injection of the additive shall be determined by agreement between the purchasing authority and the supplier. The following electrical conductivity additive is approved: Stadis® 450 marketed by Innospec Fuel Specialties LLC (formerly Octel Starreon LLC), Newark, DE 19702.

TABLE A-I. Chemical and physical requirements and test methods for 100 percent SPK.

Property	Min	Max	Test Method
Aromatics, vol percent		1	D 5186
Sulfur, total, mass percent		0.0015	D 2622, D 3120, or D 5453 [1]
Distillation temperature, °C			D 86
Initial boiling point [2]			
10 percent recovered	157	205	
20 percent recovered [2]			
50 percent recovered	168	229	
90 percent recovered	183	262	
Final boiling point		300	
Residue, vol percent		1.5	
Loss, vol percent		1.5	
Flash point, °C	38	68	D 56, D 93 [1], or D 3828
Density			D 1298 or D 4052 [1]
Density, kg/L at 15°C or	0.751	0.840	
Gravity, API at 60°F	37.0	57.0	

TABLE A-I. Chemical and physical requirements and test methods for 100 percent SPK - Continued.

Property	Min	Max	Test Method
Freezing point, °C		-47	D 2386 [1] or D 5972
Viscosity at -20°C, mm^2/s		8.0	D 445
Viscosity at 40°C, mm^2/s [2]			D 445
Net heat of combustion, MJ/kg	42.8		D 3338 or D 4809 [1]
Calculated cetane index [2]			D 976 [3] or D 4737
Naphthalenes, vol percent		0.1	D 1840
Thermal stability			D 3241
change in pressure drop, mm Hg		25	
heater tube deposit, visual rating		<3 [4]	
Particulate matter, mg/L [5]		1.0	D 2276 or D 5452 [1]
Filtration time, minutes [5]		15	
Water separation index			D 3948 or D 7224 [1]
With SDA	70		
Without SDA	85		
Electrical conductivity, pS/m [6]	150	450	D 2624

NOTES:
1. Referee Test Method.
2. To be reported – not limited.
3. Mid-boiling temperature may be obtained by ASTM D 86 to perform the cetane index calculation. ASTM D 86 values should be corrected to standard barometric pressure.
4. Peacock or Abnormal color deposits result in a failure.
5. A minimum sample size of 3.79 liters (1 gallon) shall be filtered. Filtration time will be determined in accordance with procedure in Appendix B. This procedure may also be used for the determination of particulate matter as an alternate to ASTM D 2276 or ASTM D 5452.
6. Electrical Conductivity when required per A.2.2.2 shall be determined at ambient temperature or 29.4°C (85°F), whichever is lower, unless otherwise directed by the procuring activity.

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METHOD FOR DETERMINATION OF FILTRATION TIME AND TOTAL SOLIDS

B.1 SCOPE

B.1.1 Scope. This Appendix describes the method for determining singularly or simultaneously the filterability characteristics and solids contamination of jet fuel. The purpose is to detect and prevent contaminants in jet fuel that can plug and cause rupture of ground filtration equipment, thereby affecting flight reliability of aircraft. This Appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

B.2 METHOD

B.2.1 Summary of method. 3.79 liters (1 gallon) of jet fuel is filtered through a membrane filter in the laboratory. The time required to filter this volume is measured in minutes and solids content is determined gravimetrically.

B.3 APPARATUS

a. Membrane filter: White, plain, 47 mm diameter, nominal pore size 0.8 µm. The membrane filter must be approved by ASTM for use with ASTM D 5452.

b. Filtration apparatus: The apparatus, constructed of stainless steel, consists of a funnel and a funnel base with a filter support such that a membrane filter and a flow reducing washer can be securely held between the sealing surface of the funnel and funnel base (see Figure 2 in ASTM D 5452).

c. Flow reducing washer: A 47-mm diameter flow reducer washer with an effective filtration area of 4.8 cm^2 (Millipore Corporation Part No. XX10 04710).

d. Vacuum flask: A minimum of 4 liters.

e. Vacuum system: That develops in excess of 67.5 kPa (20 inches of mercury) vacuum.

f. Oven: Of the static type (without fan assisted circulation) controlling to 90° ± 5° C (194° ± 9° F).

g. Forceps: Flat-bladed with unserrated nonpointed tips.

h. Dispenser, rinsing solvent (petroleum ether): Containing a 0.45 µm membrane filter in the delivery line. If solvent has been pre-filtered using a 0.45 µm filter then an inline filter is not required.

i. Glass petri dish: Approximately 125 mm in diameter with removable cover.

j. Analytical balance: Single or double pan, the precision standard deviation of which must be 0.07 mg or better.

B.4 PREPARATION

B.4.1 Preparation of apparatus and sample containers. All components of the filtration apparatus (except the vacuum flask), sample containers and caps must be cleaned as described in paragraph 9 of ASTM D 5452. All metal parts of the filtration apparatus are to be electrically bonded and grounded, including the fuel sample container. See ASTM D 5452 for other safety precautions.

B.5 SAMPLING

B.5.1 Sampling. Obtain a representative 3.79 L (1 gallon) sample as directed in paragraph 8 of ASTM D 5452. When sampling from a flowing stream is not possible, an all level sample or an average sample, in accordance with ASTM D 4057 and/or ASTM D 4177 shall be permitted. The 3.79 L (1 gallon) sample container shall be an interior epoxy-coated metal can, a brown glass bottle, or a clear glass bottle protected by suitable means from exposure to light.

B.6 PROCEDURE

B.6.1 Test procedure.

a. Using forceps, place a new membrane (test) filter in a clean petri dish. Place the petri dish with the lid slightly ajar in a 90 ± 5°C oven for 30 minutes. Remove the petri dish from the oven and place it near the balance with the lid slightly ajar, but still protecting the filter from airborne contamination, for 30 minutes.

b. Weigh the test filter. A filter weighing in excess of 90 mg will not be used for time filtration testing.

c. Place a flow reducing washer (required only for time filtration testing) on top of funnel base then place a test filter on top of the reducing washer and secure the funnel to the funnel base.

d. Immediately prior to filtering the fuel, shake the sample to obtain a homogeneous mix and assure that fuel temperature does not exceed 30°C (86°F). Clean the exterior or top portion of the sample container to ensure that no contaminants are introduced. Any free water present in the fuel sample will invalidate the filtration time results by giving an excessive filtration time rating.

e. With the vacuum off, pour approximately 200 mL of fuel into the funnel.

f. Turn vacuum on and record starting time. Continue filtration of the 3.79 liters (1 gallon) sample, periodically shaking the sample container to maintain a homogenous mix. Record the vacuum (kPa or inches of mercury) 1 minute after start and again immediately prior to completion of filtration. Throughout filtration, maintain a sufficient quantity of fuel in the funnel so that the membrane filter is always covered.

g. Report the filtration time in minutes expressed to the nearest whole number. If filtration of the 3.79 liters (1 gallon) is not completed within 30 minutes, the test will be stopped and the volume of the fuel filtered will be measured. In these cases, report filtration time as ">30 minutes" and the total volume of fuel filtered.

h. Report the vacuum (kPa or inches of mercury) as determined from the average of the two readings taken in B.6.f.

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i. After recording the filtration time, shut off the vacuum and rinse the sample container with approximately 100 mL of filtered petroleum ether and dispense into the filtration funnel. Turn vacuum on and filter the 100 mL rinse. Turn vacuum off and wash the inside of the funnel with approximately 50 mL of filtered petroleum ether. Turn vacuum on and filter. Repeat the funnel rinse with another 50 mL of petroleum ether but allow the rinse to soak the filter for approximately 30 seconds before turning the vacuum on to filter the rinse. With vacuum on, carefully remove the top funnel and rinse the periphery of the filter by directing a gentle stream of petroleum ether from the solvent dispenser from the edge of the filter toward the center, taking care not to wash contaminants off the filter. Maintain vacuum after final rinse for a few seconds to remove the excess petroleum ether from the filter.

j. Using forceps, carefully remove test filter (from the funnel base and flow reducing washer if present) and place in a clean petri dish. Dry in the oven at 90° ± 5°C (194° ± 9°F) for 30 minutes with the cover on the petri dish slightly ajar. Remove the petri dish from the oven and place it near the balance with the lid slightly ajar, but still protecting the filter from airborne contamination, for 30 minutes. Reweigh the filter.

k. Report the total solids content in mg/liter by using the following formula:

$$\frac{\text{Weight gain of filter in mg}}{3.785} = \text{mg/liter}$$

l. Should the sample exceed the 30-minute filtration time and a portion of the fuel is not filtered, the solids content in mg/liter will be figured as follows: Determine the volume of fuel filtered by subtracting the mL of fuel remaining from 3.785.

$$\frac{\text{Weight gain of filter in mg}}{\text{mL of fuel filtered} \times 0.001} = \text{mg/liter}$$

B.7 Test conditions for filtration time

a. The vacuum should exceed 67.5 kPa (20 inches of mercury) throughout the test. The differential pressure across the filter should exceed 67.5 kPa (20 inches of mercury).

b. The fuel temperature shall be between 18° and 30°C (64° and 86°F). If artificial heat (such as a hot water bath) is used to heat the sample, erroneously high filtration times may occur, but this approach is allowed.

B.8 NOTES

B.8.1 Filtration time. If it is desired to determine the filtration time and not the total solids content, perform the test by omitting steps B.6.1i, B.6.1j, B.6.1k, and B.6.1l.

B.8.2 Total solids. If it is desired to determine the total solids content and not the filtration time, use of the flow reducing washer may be omitted. It is also permissible, but not required, to use a control filter for a specific analysis or a series of analyses. When this is accomplished, the procedures specified in ASTM D 5452 apply.

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CONCLUDING MATERIAL

Custodians:
Navy – AS
Army – MR
Air Force – 68
DLA – PS

Preparing activity:
Air Force – 68
(Project 9130-2007-001)

Review activities:
Army – AR, AV, AT
Air Force – 11

Note: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information using the ASSIST Online database at http://assist.daps.dla.mil.

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APPENDIX 3

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ICAO Aircraft Engine Emissions Databank

Civil Aviation Authority

Contents

1. Data Sources
2. Background
3. Revision of data
4. Contacts
5. Use of the Data Bank
6. Definitions
7. Regulatory standards
8. References

1. Data Sources

This Databank contains information on exhaust emissions of only those aircraft engines that have entered production. The information was provided by engine manufacturers, who are solely responsible for its accuracy. It was collected in the course of the work carried out by the ICAO Committee on Aviation Environmental Protection (CAEP) but has not been independently verified unless indicated. The UK CAA is hosting this Databank on behalf of ICAO and is not responsible for the contents.

2. Background

Standards limiting the emissions of smoke, unburnt hydrocarbons (HC), carbon monoxide (CO) and oxides of nitrogen (NO_x) from turbojet and turbofan aircraft engines are contained in Annex 16 Volume II (Second Edition, July 1993, plus amendments) [Reference 1] to the Convention on International Civil Aviation. The Annex also contains approved test and measurement procedures.

With respect to subsonic applications, the provisions of the Standards for smoke apply to engines whose date of manufacture is on or after 1 January 1983. For the gaseous emissions, the Standards apply only to engines whose rated output is greater than 26.7 kN. For hydrocarbons and carbon monoxide, they apply to engines whose date of manufacture is on or after 1 January 1986. For oxides of nitrogen, the Standards have several levels of stringency depending on the date of manufacture of the engine. These Standards are summarized later in Section 7.

This Databank contains information on exhaust emissions of only those engines that have entered production, irrespective of the numbers actually produced. It has been compiled mainly from information supplied for newly certified engines. However, for some engines, the data has been revised to reflect evidence from subsequent engine tests. It also includes data on older engines which did not have to comply with the emissions standards and some data from a very limited number of in-service engines measured before or after overhaul.

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The original version was published as a printed document [Reference 2]. All subsequent updates have been electronic

3. Revision of data

The electronic version of the Databank is updated at periodic intervals. New data are included for:

a) engines certificated since the last issue of the data bank;
b) engines already certificated for which data were not previously available; or
c) engines already certificated and listed in the Databank for which:
   i. emissions data have been recalculated as a result of a better definition of engine performance characteristics with continuing production of an engine type;
   ii. component design changes have been introduced which affect the emissions levels, e.g. new combustor design; or
   iii. improvements in emissions measurement techniques have resulted in changes to the emissions data.

Data will not be removed from the Databank. Where data is superseded the row is marked to indicate that this data should not be used, and the newer data to be used instead is specified. Data is also marked where an engine is no longer in service, and where an engine is no longer in production.

The Record of Changes documents the history of revisions, and the date of latest review.

4. Contacts

New data should be submitted to:

Aircraft Environmental Section
Aircraft Certification Department
Safety Regulation Group
Civil Aviation Authority
Aviation House
Gatwick Airport South
West Sussex
RH6 0YR
United Kingdom

email: Emissions.Databank@srg.caa.co.uk
phone: (+44) 1293 573204

Comments and queries concerning this electronic version of the database should also be sent to the above address.

5. Use of the Databank

The user of the Databank should note the limitations in the emissions data; i.e.:

a) The D_p/F_{oo} values are based on an idealized Landing/Take-Off (LTO) cycle in International Standard Atmosphere (ISA) conditions. In assessing, for example, total aircraft emissions at a specific airport, consideration must be given to the appropriateness of the prescribed thrusts, the times in mode and the reference conditions.

b) The LTO cycle only assesses the emissions below 915 m (3 000 ft) and therefore may not be a good guide for comparing the emissions of different engines in other flight modes, e.g. cruise.

6. Definitions

By-pass ratio: The ratio of the air mass flow through the by-pass ducts of a gas turbine engine to the air mass flow through the engine core, calculated at maximum thrust when the engine is stationary in an international standard atmosphere at sea level.

Characteristic level: The characteristic level of a gaseous pollutant or smoke is the mean D_p/F_{oo} or SN value of a species, for all the engines tested, measured and corrected to the reference standard engine and reference atmospheric conditions, divided by a coefficient corresponding to the number of engines tested. The procedure and coefficients are given in Annex 16, Volume II. This is in recognition that at the certification stage there are usually not many engines to production standard available for testing, so the manufacturer is allowed to select any number of engines, including a single engine if so desired, for testing. Statistically derived coefficients, corresponding to the number of engines tested, are then applied to ensure a high confidence that the mean of the anticipated total engine production will not exceed the regulatory level. The procedure and coefficients are given in Annex 16 Volume II, Appendix 6.

Data Status: This has been grouped into three categories:

1. *Pre-regulation:* Data obtained on engines generally prior to the promulgation of the Standards of Annex 16, Volume II, and for which the manufacturer was not required to apply for emissions certification.

2. *Certification:* Data which have been submitted for certification approval after the applicability dates or which have been obtained at an earlier date, generally after the promulgation of the Standards of Annex 16. Volume II, with the intention of gaining approval.

3. *Revised:* Existing data which have been modified, as noted in paragraph c) under REVISION OF DATA above, and which do not require the engine to be re-certificated.

D_p/F_{oo}: The mass, in grams (D_p), of any pollutant emitted during the reference landing and take-off (LTO) cycle, divided by the rated output (F_{oo}) of the engine.

Emissions index (EI): The mass of pollutant (CO, HC or NO_x), in grams, divided by the mass of fuel used in kilograms.

Fuel: The fuel used is aviation kerosene as specified in Annex 16, Volume II, Appendix 4.

Hydrocarbons (HC): The total of hydrocarbon compounds of all classes and molecular weights contained in a gas sample, calculated as if they were in the form of methane.

International Standard Atmosphere (ISA): The atmosphere defined in the Manual of the ICAO Standard Atmosphere (Doc 7488). These are the atmospheric conditions to which all engine performance data should be corrected.

LTO cycle: The reference emissions LTO cycle defines the thrust settings to be used when making emissions and smoke measurements and the time to be used for each mode in the subsequent calculations of D_p. These thrust settings and times are listed in Annex 16, Volume II, Part III, Chapter 2 (engines for subsonic propulsion).

Oxides of nitrogen (NO_x): The sum of the amounts of the nitric oxide and nitrogen dioxide contained in a gas sample calculated as if the nitric oxide were in the form of nitrogen dioxide.

Pressure ratio (π_{oo}): The ratio of the mean total pressure at the last compressor discharge plane of the compressor to the mean total pressure at the compressor entry plane when the engine is developing take-off thrust rating in ISA sea level static conditions.

Rated output (F_{oo}): The maximum thrust available for take-off under normal operating conditions at ISA sea level static conditions without the use of water injection as approved by the certificating authority. Thrust is expressed in kilonewtons.

Reference Atmospheric Conditions: The atmospheric conditions to which all emissions results should be corrected. The reference atmospheric conditions are ISA at sea level except that the reference absolute humidity shall be 0.00634 kg water/kg dry air.

Regulatory Level: The level below which the characteristic D_p/F_{oo} or Smoke Number value for a pollutant species must fall in order to obtain certification approval. The regulatory levels reproduced from Annex 16, Volume II, Part III, Chapters 2 (subsonic engines) are given below in Section 7.

Smoke Number (SN): The dimensionless term quantifying smoke emissions. Smoke Number is calculated from the reflectance of a filter paper measured before and after the passage of a known volume of a smoke-bearing sample.

7. Regulatory standards

These applicability requirements and regulatory levels are those found in Annex 16, Volume II, Part III, Chapter 2 (subsonic engines) and are included for reference purposes only.

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Smoke

Applicability
The regulatory levels are applicable to engines whose date of manufacture is on or after 1 January 1983.

Regulatory smoke number
The characteristic level of the smoke number at any thrust setting, measured in accordance with Annex 16, Volume II, must not exceed 83.6 $(F_{oo})^{-0.274}$ or a value of 50, whichever is lower.

Gaseous emissions

Applicability
The regulatory levels apply to engines whose rated output is greater than 26.7kN and whose date of manufacture is on or after 1 January 1986 and as further specified for oxides of nitrogen.

Regulatory levels
The characteristic levels of the gaseous emissions measured over the LTO cycle in accordance with Annex 16, Volume II, must not exceed the following regulatory levels:

Hydrocarbons (HC): $D_p/F_{oo} = 19.6$

Carbon monoxide (CO): $D_p/F_{oo} = 118$

Oxides of nitrogen (NOx):

a) for engines of a type or model of which the date of manufacture of the first individual production model was on or before 31 December 1995 and for which the date of manufacture of the individual engine was on or before 31 December 1999:

$$D_p/F_{oo} = 40 + 2\pi_{oo}$$

b) for engines of a type or model of which the date of manufacture of the first individual production model was after 31 December 1995 or for which the date of manufacture of the individual engine was after 31 December 1999:

$$D_p/F_{oo} = 32 + 1.6\pi_{oo}$$

c) for engines of a type or model of which the date of manufacture of the first individual production model was after 31 December 2003:

1. for engines with a pressure ratio of 30 or less:

    i. for engines with a maximum rated thrust of more than 89.0 kN:

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$$D_p/F_{oo} = 19 + 1.6\pi_{oo}$$

ii. for engines with a maximum rated thrust of more than 26.7 kN but not more than 89.0 kN:

$$D_p/F_{oo} = 37.572 + 1.6\pi_{oo} - 0.2087F_{oo}$$

2. for engines with a pressure ratio of more than 30 but less than 62.5:

i. for engines with a maximum rated thrust of more than 89.0 kN:

$$D_p/F_{oo} = 7 + 2.0\pi_{oo}$$

ii. for engines with a maximum rated thrust of more than 26.7 kN but not more than 89.0 kN:

$$D_p/F_{oo} = 42.71 + 1.4286\pi_{oo} - 0.4013F_{oo} + 0.00642\pi_{oo} \times F_{oo}$$

3) for engines with a pressure ratio of 62.5 or more:

$$D_p/F_{oo} = 32 + 1.6\pi_{oo}$$

d) for engines of a type or model of which the date of manufacture of the first individual production model was after 31 December 2007:

1) for engines with a pressure ratio of 30 or less:

i. for engines with a maximum rated thrust of more than 89.0 kN:

$$D_p/F_{oo} = 16.72 + 1.4080\pi_{oo}$$

ii. for engines with a maximum rated thrust of more than 26.7 kN but not more than 89.0 kN:

$$D_p/F_{oo} = 38.5486 + 1.6823\pi_{oo} - 0.2453F_{oo} - 0.00308\pi_{oo} \times F_{oo}$$

2) for engines with a pressure ratio of more than 30 but less than 82.6:

i. for engines with a maximum rated thrust of more than 89.0 kN:

$$D_p/F_{oo} = -1.04 + 2.0\pi_{oo}$$

ii. for engines with a maximum rated thrust of more than 26.7 kN but not more than 89.0 kN:

$$D_p/F_{oo} = 46.1600 + 1.4286\pi_{oo} - 0.5303F_{oo} + 0.00642\pi_{oo} \times F_{oo}$$

3) for engines with a pressure ratio of 82.6 or more:

$$D_p/F_{oo} = 32 + 1.6\pi_{oo}$$

8. References

1. ICAO Annex 16 "International standards and recommended practices, Environmental protection", Volume II "Aircraft engine emissions", 2nd ed. (1993) plus amendments:

Amendment 3,	20 March 1997;
Amendment 4,	4 November 1999;
Amendment 5,	24 November 2005

2. ICAO Engine Exhaust Emissions Databank, First Edition 1995, ICAO, Doc 9646- AN/943.

ICAO ENGINE EXHAUST EMISSIONS DATA BANK

SUBSONIC ENGINES

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ENGINE IDENTIFICATION:	CFM56-3C-1	BYPASS RATIO:	5.1
UNIQUE ID NUMBER:	1CM007	PRESSURE RATIO (π_{oo}):	25.5
ENGINE TYPE:	TF	RATED OUTPUT (F_{oo}) (kN):	104.6

REGULATORY DATA

CHARACTERISTIC VALUE:	HC	CO	NOx	SMOKE NUMBER
D_p/F_{oo} (g/kN) or SN	4.3	65.7	53.1	9.9
AS % OF ORIGINAL LIMIT	21.7 %	55.7 %	58.3 %	42.4 %
AS % OF CAEP/2 LIMIT (NOx)			72.9 %	
AS % OF CAEP/4 LIMIT (NOx)			88.8 %	

DATA STATUS

- \- PRE-REGULATION
- \- CERTIFICATION
- x REVISED (SEE REMARKS)

TEST ENGINE STATUS

- x NEWLY MANUFACTURED ENGINES
- \- DEDICATED ENGINES TO PRODUCTION STANDARD
- \- OTHER (SEE REMARKS)

EMISSIONS STATUS

x DATA CORRECTED TO REFERENCE (ANNEX 16 VOLUME II)

CURRENT ENGINE STATUS

(IN PRODUCTION, IN SERVICE UNLESS OTHERWISE NOTED)

- x OUT OF PRODUCTION (DATE: -)
- \- OUT OF SERVICE

MEASURED DATA

MODE	POWER SETTING (%F_{oo})	TIME minutes	FUEL FLOW kg/s	EMISSIONS INDICES (g/kg) HC	CO	NOx	SMOKE NUMBER
TAKE-OFF	100	0.7	1.154	0.03	0.9	20.7	7.7
CLIMB OUT	85	2.2	0.954	0.04	0.9	17.8	3.9
APPROACH	30	4.0	0.336	0.07	3.1	9.1	2.5
IDLE	7	26.0	0.124	1.42	26.8	4.3	2.3
LTO TOTAL FUEL (kg) or EMISSIONS (g)			448	287	5591	4810	-
NUMBER OF ENGINES				1	1	1	1
NUMBER OF TESTS				3	3	3	3
AVERAGE D_p/F_{oo} (g/kN) or AVERAGE SN (MAX)				2.76	53.5	45.8	7.7
SIGMA (D_p/F_{oo} in g/kN, or SN)				0.38	2.85	0.82	0.76
RANGE (D_p/F_{oo} in g/kN, or SN)				2.33-3.06	51.2-56.7	45.3-46.8	6.8-8.3

ACCESSORY LOADS

POWER EXTRACTION	0	(kW)	AT	-	POWER SETTINGS
STAGE BLEED	0	% CORE FLOW	AT	-	POWER SETTINGS

ATMOSPHERIC CONDITIONS

BAROMETER (kPa)	95.98-97.49
TEMPERATURE (K)	279 - 286
ABS HUMIDITY (kg/kg)	.002-.009

FUEL

SPEC	Jet A
H/C	1.93
AROM (%)	16

MANUFACTURER: CFMI
TEST ORGANIZATION: CFM56 Evaluation Engineering
TEST LOCATION: Peebles Site IVD
TEST DATES: FROM 11 Nov 83 TO 14 Nov 83

REMARKS

1. Ref GE Report R84AEB579.
2. Engine S/N 692441.
3. Revised based on 3/89 production status cycle.

ICAO ENGINE EXHAUST EMISSIONS DATA BANK

SUBSONIC ENGINES

III, 10

ENGINE IDENTIFICATION:	CF6-50C1, -C2	BYPASS RATIO:	4.3
UNIQUE ID NUMBER:	1GE007	PRESSURE RATIO (π_{oo}):	29.8
ENGINE TYPE:	TF	RATED OUTPUT (F_{oo}) (kN):	230.4

REGULATORY DATA

CHARACTERISTIC VALUE:	HC	CO	NOx	SMOKE NUMBER
D_p/F_{oo} (g/kN) or SN	37.3	99.0	64.3	4.8
AS % OF ORIGINAL LIMIT	190.1 %	83.9 %	64.6 %	25.5 %
AS % OF CAEP/2 LIMIT (NOx)			80.7 %	
AS % OF CAEP/4 LIMIT (NOx)			96.5 %	

DATA STATUS

- x PRE-REGULATION
- \- CERTIFICATION
- \- REVISED (SEE REMARKS)

TEST ENGINE STATUS

- x NEWLY MANUFACTURED ENGINES
- \- DEDICATED ENGINES TO PRODUCTION STANDARD
- \- OTHER (SEE REMARKS)

EMISSIONS STATUS

- x DATA CORRECTED TO REFERENCE (ANNEX 16 VOLUME II)

CURRENT ENGINE STATUS

(IN PRODUCTION, IN SERVICE UNLESS OTHERWISE NOTED)

- x OUT OF PRODUCTION (DATE: -)
- \- OUT OF SERVICE

MEASURED DATA

MODE	POWER SETTING (%F_{oo})	TIME minutes	FUEL FLOW kg/s	EMISSIONS INDICES (g/kg) HC	CO	NOx	SMOKE NUMBER
TAKE-OFF	100	0.7	2.487	0.6	0.5	36.3	4.1
CLIMB OUT	85	2.2	1.975	0.7	0.5	29.7	2.7
APPROACH	30	4.0	0.66	1	4.3	9.5	2.7
IDLE	7	26.0	0.215	21.8	61.8	3.6	4.5
LTO TOTAL FUEL (kg) or EMISSIONS (g)			859	7715	21591	14247	-
NUMBER OF ENGINES				6	6	6	6
NUMBER OF TESTS				6	6	6	6
AVERAGE D_p/F_{oo} (g/kN) or AVERAGE SN (MAX)				33.5	93.7	61.8	4.5
SIGMA (D_p/F_{oo} in g/kN, or SN)				3.8	4.6	0.5	1.5
RANGE (D_p/F_{oo} in g/kN, or SN)				-	-	-	-

ACCESSORY LOADS

POWER EXTRACTION	0	(kW)	AT	-	POWER SETTINGS
STAGE BLEED	0	% CORE FLOW	AT	-	POWER SETTINGS

ATMOSPHERIC CONDITIONS

BAROMETER (kPa)	98.3-100.4
TEMPERATURE (K)	270 - 296
ABS HUMIDITY (kg/kg)	.0027-.0103

FUEL

SPEC	Jet A
H/C	1.92
AROM (%)	17.1

MANUFACTURER: GE Aircraft Engines
TEST ORGANIZATION: Production Engine Test
TEST LOCATION: Production Test Cells M34 & M35
TEST DATES: FROM 12 Oct 79 TO 05 Dec 79

REMARKS

Ref Report no FAA-EE-80-27 (GE Report R80AEG420)

ICAO ENGINE EXHAUST EMISSIONS DATA BANK

SUBSONIC ENGINES

III, 11

** DATA SUPERSEDED ** SEE SHEET: 8PW089

ENGINE IDENTIFICATION: PW4084
UNIQUE ID NUMBER: 2PW062
ENGINE TYPE: TF

BYPASS RATIO: 6.4
PRESSURE RATIO (π_{oo}): 36.2
RATED OUTPUT (F_{oo}) (kN): 369.6

REGULATORY DATA

CHARACTERISTIC VALUE:	HC	CO	NOx	SMOKE NUMBER
D_p/F_{oo} (g/kN) or SN	4.5	23.0	72.8	13.5
AS % OF ORIGINAL LIMIT	23.0 %	19.5 %	64.8 %	81.6 %
AS % OF CAEP/2 LIMIT (NOx)			81.0 %	
AS % OF CAEP/4 LIMIT (NOx)			91.7 %	

DATA STATUS

- PRE-REGULATION
x CERTIFICATION
- REVISED (SEE REMARKS)

TEST ENGINE STATUS

- NEWLY MANUFACTURED ENGINES
x DEDICATED ENGINES TO PRODUCTION STANDARD
- OTHER (SEE REMARKS)

EMISSIONS STATUS

x DATA CORRECTED TO REFERENCE (ANNEX 16 VOLUME II)

CURRENT ENGINE STATUS

(IN PRODUCTION, IN SERVICE UNLESS OTHERWISE NOTED)
- OUT OF PRODUCTION
- OUT OF SERVICE

MEASURED DATA

MODE	POWER SETTING (%F_{oo})	TIME minutes	FUEL FLOW kg/s	EMISSIONS INDICES (g/kg) HC	CO	NOx	SMOKE NUMBER
TAKE-OFF	100	0.7	3.411	0.1	0.1	45	10.5
CLIMB OUT	85	2.2	2.689	0.1	0.1	35.5	-
APPROACH	30	4.0	0.875	0.2	0.4	12	-
IDLE	7	26.0	0.242	2.7	18.73	4.4	-
LTO TOTAL FUEL (kg) or EMISSIONS (g)			1086	1111	7205	23229	-
NUMBER OF ENGINES				1	1	1	1
NUMBER OF TESTS				3	3	3	3
AVERAGE D_p/F_{oo} (g/kN) or AVERAGE SN (MAX)				2.9	19.5	62.8	10.5
SIGMA (D_p/F_{oo} in g/kN, or SN)				-	-	-	-
RANGE (D_p/F_{oo} in g/kN, or SN)				-	-	-	-

ACCESSORY LOADS

POWER EXTRACTION 0 (kW) AT - POWER SETTINGS
STAGE BLEED 0 % CORE FLOW AT - POWER SETTINGS

ATMOSPHERIC CONDITIONS

BAROMETER (kPa)	101.3
TEMPERATURE (K)	288
ABS HUMIDITY (kg/kg)	0.0063

FUEL

SPEC	Jet A
H/C	1.92
AROM (%)	20.3

MANUFACTURER: Pratt and Whitney
TEST ORGANIZATION: Pratt and Whitney
TEST LOCATION: East Hartford, Ct, USA
TEST DATES: FROM 26 Apr 94 TO 02 May 94

REMARKS

Data from X832-4

If REVISED, this data supersedes databank UID 8PW090
Compliance with fuel venting requirements: - ('x' if complies, PR if pre-regulation)

ICAO ENGINE EXHAUST EMISSIONS DATA BANK

SUBSONIC ENGINES

III, 12

ENGINE IDENTIFICATION:	JT3D-3B	BYPASS RATIO:	1.4
UNIQUE ID NUMBER:	1PW001	PRESSURE RATIO (π_{oo}):	13.6
ENGINE TYPE:	TF	RATED OUTPUT (F_{oo}) (kN):	80.06

REGULATORY DATA

CHARACTERISTIC VALUE:	HC	CO	NOx	SMOKE NUMBER
D_p/F_{oo} (g/kN) or SN	395.4	328.2	37.7	63.9
AS % OF ORIGINAL LIMIT	2,017.6 %	278.2 %	56.1 %	254.1 %
AS % OF CAEP/2 LIMIT (NOx)			70.2 %	
AS % OF CAEP/4 LIMIT (NOx)			88.3 %	

DATA STATUS

- x PRE-REGULATION
- \- CERTIFICATION
- \- REVISED (SEE REMARKS)

TEST ENGINE STATUS

- \- NEWLY MANUFACTURED ENGINES
- x DEDICATED ENGINES TO PRODUCTION STANDARD
- \- OTHER (SEE REMARKS)

EMISSIONS STATUS

- x DATA CORRECTED TO REFERENCE (ANNEX 16 VOLUME II)

CURRENT ENGINE STATUS

(IN PRODUCTION, IN SERVICE UNLESS OTHERWISE NOTED)

- x OUT OF PRODUCTION (DATE: -)
- \- OUT OF SERVICE

MEASURED DATA

MODE	POWER SETTING (%F_{oo})	TIME minutes	FUEL FLOW kg/s	EMISSIONS INDICES (g/kg) HC	CO	NOx	SMOKE NUMBER
TAKE-OFF	100	0.7	1.174	4	1.5	12.1	-
CLIMB OUT	85	2.2	0.932	2	2.8	9.9	-
APPROACH	30	4.0	0.346	4	24.5	4.8	-
IDLE	7	26.0	0.135	112	98	2.5	-
LTO TOTAL FUEL (kg) or EMISSIONS (g)			466	24363	23092	2740	-
NUMBER OF ENGINES				2	2	2	2
NUMBER OF TESTS				-	-	-	-
AVERAGE D_p/F_{oo} (g/kN) or AVERAGE SN (MAX)				303.9	288.1	34.3	54.5
SIGMA (D_p/F_{oo} in g/kN, or SN)				-	-	-	-
RANGE (D_p/F_{oo} in g/kN, or SN)				-	-	-	-

ACCESSORY LOADS

POWER EXTRACTION	0	(kW)	AT	-	POWER SETTINGS
STAGE BLEED	0	% CORE FLOW	AT	-	POWER SETTINGS

ATMOSPHERIC CONDITIONS

BAROMETER (kPa)	-
TEMPERATURE (K)	-
ABS HUMIDITY (kg/kg)	-

FUEL

SPEC	Jet A
H/C	-
AROM (%)	-

MANUFACTURER: Pratt & Whitney
TEST ORGANIZATION: P&WA
TEST LOCATION: East Hartford, CT, USA.
TEST DATES: FROM 08 Mar 72 TO 12 Sep 74

REMARKS

Emissions data estimated from JT3D-7 engines using JT3D-3B performance data.

IV, 1

APPENDIX 4

IV, 2

WMO Meteorological codes

This document gives details of the Meteorological codes for use at observing stations.

Type / Genus of cloud:

```
WMO code 0500: Genus of cloud

/ - cloud not visible owing to darkness, fog, duststorm, sandstorm or other
    analogous phenomena
0 - cirrus  (CI)
1 - cirricumulus (CC)
2 - cirrostratus (CS)
3 - altocumulus (AC)
4 - altostratus (AS)
5 - nimbostratus (NS)
6 - stratocumulus (SC)
7 - stratus (ST)
8 - cumulus (CU)
9 - cumulonimbus (CB)
```

High cloud type:

```
WMO code 0509:Clouds of genera Cirrus, Cirrocumulus and Cirrostratus.

/ - cirrus, cirrocumulus & cirrostratus invisible owing to darkness, fog, blowing
    dust or sand, or other phenomena, or more often because of the presence of a
    continuous layer of lower clouds
0 - no cirrus, cirrocumulus or cirrostratus clouds
1 - cirrus in the form of filaments, strands or hooks, not progressively invading
    the sky.
2 - dense cirrus, in patches or entangled sheaves, which usually do not increase
    & sometimes seem to be the remains of the upper part of a cumulonimbus; or
    cirrus with sproutings in the form of small turrets; or cirrus having the
    appearance of cumuliform tufts
3 - dense cirrus, often in the form of an anvil, being the remains of the upper
    part of cumulonimbus
4 - cirrus in the form of hooks, filaments, or both, progressively invading the
    sky; they generally become denser as a whole.
5 - cirrus (often in bands converging towards 1 point or 2 opposite points of
    the horizon) and cirrostratus, or cirrostratus alone;in either case, they
    are progressively invading the sky, and generally growing denser as a whole,
    but the continuous veil does not reach 45 degrees above the horizon.
6 - cirrus (often in bands converging towards 1 point or 2 opposite points of
    the horizon) and cirrostratus, or cirrostratus alone;in either case, they
    are progressively invading the sky, and generally growing denser as a whole;
    the continuous veil extends more than 45 degrees above the horizon, without
    the sky being totally covered.
7 - veil of cirrostratus covering the celestial dome
8 - cirrostratus not progressively invading the sky and not completely covering
    the celestial dome.
9 - cirrocumulus alone, or cirrocumulus accompanied by cirrus or cirrostratus, or
    both, but cirrocumulus is predominant
```

Low cloud type:

```
WMO code 0513: Clouds of genera Stratocumulus, Stratus, Cumulus, etc.

/ - stratocumulus, stratus, cumulus and cumulonimbus invisible owing to darkness,
    fog, blowing dust or sand, or other phenomena
0 - no stratocumulus, stratus, cumulus or cumulonimbus
1 - cumulus with little vertical extent and seemingly flattened, or ragged
    cumulus, other than of bad weather, or both
2 - cumulus of moderate or strong vertical extent, generally with protuberances
    in the form of domes or towers, either accompanied or not by other cumulus
    or stratocumulus, all having bases at the same level
3 - cumulonimbus, the summits of which, at least partially, lack sharp outlines
    but are neither clearly fibrous (cirriform) nor in the form of an anvil;
    cumulus, stratocumulus or stratus may also be present
4 - stratocumulus formed by the spreading out of cumulus; cumulus may also be
    present
5 - stratocumulus not resulting from the spreading out of cumulus
6 - stratus in a more or less continuous later, or in ragged shreds, or both but
    no stratus fractus of bad weather
7 - stratus fractus of bad weather or cumulus fractus of bad weather, or both
    (pannus), usually below altostratus or nimbostratus
8 - cumulus and stratocumulus other than that formed from the spreading out of
    cumulus; the base of the cumulus is at a different level from that of the
    stratocumulus
9 - cumulonimbus, the upper part of which is clearly fibrous (cirriform) often in
    the form of an anvil; either accompanied or not by cumulonimbus without anvil
    or fibrous upper part, by cumulus, stratocumulus, stratus or pannus
```

Medium cloud type:

```
WMO code 0515: Clouds of the genera Altocumulus, Altostratus, etc.

/ - altocumulus, altostratus and nimbostratus invisible owing to darkness, fog,
```

IV, 3

```
    blowing dust, sand, or other phenomena; or because of the presence of a
    continuous layer of lower clouds
0 - no altocumulus, altostratus or nimbostratus
1 - altostratus, the greater part of which is semi-transparent; through this part
    the sun or moon may be weakly visible, as through ground glass
2 - altostratus, the greater part of which is sufficiently dense to hide the sun
    or moon, or nimbostratus
3 - altocumulus, the greater part of which is semi-transparent; the various
    elements of the cloud change only slowly and are all at a single level
4 - patches (often in the form of almonds or fish) of altocumulus, the greater
    part of which is semi-transparent; the clouds occur at one or more levels
    and the elements are continually changing in appearance
5 - semi-transparent altocumulus in bands, or altocumulus, in one or more
    continuous layer (semi-transparent or opaque), progressively invading the
    sky; these generally thicken as a whole
6 - altocumulus resulting from the spreading out of cumulus or cumulonimbus
7 - altocumulus in two or more layers, usually opaque in places, and not
    progressively invading the sky; or opaque layer of altocumulus,not
    progressively invading the sky; or altocumulus together with altostratus
    or nimbostratus
8 - altocumulus with sproutings in the form of small towers or battlements, or
    altocumulus having the appearance of cumuliform tufts
9 - altocumulus of a chaotic sky, generally at several levels
```

State of ground:

WMO code 0901: **State of ground <u>without</u> snow or measurable ice cover.**

```
0 - ground dry (no cracks or appreciable amounts of dust/loose sand)
1 - ground moist
2 - ground wet (standing water in small or large pools on surface)
3 - flooded
4 - ground frozen
5 - glaze on ground
6 - loose dry dust or sand not covering ground completely
7 - thin cover of loose dry dust or sand covering ground completely
8 - mod/thick cover of loose dry dust/sand covering ground completely
9 - extremely dry with cracks
```

WMO code 0975: **State of ground <u>with</u> snow or measurable ice cover.**

```
0 - ground predominantly covered by ice
1 - compact/wet snow (with or without ice) covering less than 1/2 the ground
2 - compact/wet snow (with or without ice) covering at least 1/2 the ground
3 - even layer of compact or wet snow covering ground completely
4 - uneven layer of compact or wet snow covering ground completely
5 - loose dry snow covering less than 1/2 the ground
6 - loose dry snow covering at least 1/2 the ground (not completely)
7 - even layer of loose dry snow covering ground completely
8 - uneven layer or loose dry snow covering ground completely
9 - snow covering ground completely; deep drifts
```

Total cloud amount:

WMO code 2700: **Cloud cover / amount**

```
/ - cloud is indiscernible for reasons other than fog or other meteorological
    phenomena, or observation is not made.
0 - sky clear
1 - 1 okta : 1/10 - 2/10
2 - 2 oktas : 2/10 - 3/10
3 - 3 oktas : 4/10
4 - 4 oktas : 5/10
5 - 5 oktas : 6/10
6 - 6 oktas : 7/10 - 8/10
7 - 7 oktas or more, but not 8 oktas : 9/10 or more, but not 10/10
8 - 8 oktas : 10/10
9 - sky obscured by fog or other meteorological phenomena
```

Past weather:

Past weather is defined as weather occurring in the past 6 hours at 00, 06, 12, 18 UTC, and the past 3 hours at 03, 09, 15, 21 UTC.

WMO code 4561: **Past weather**

```
0 - cloud covering half or less of the sky throughout the period
1 - cloud covering more than half the sky during part of the period & half or
    less for the rest
2 - cloud covering more than half the sky throughout the period
3 - sandstorm, duststorm or blowing snow
4 - fog or ice fog or thick haze
5 - drizzle
6 - rainl
7 - snow, or rain and snow mixed
8 - shower(s)
9 - thunderstorm(s) with or without precipitation
```

Present weather:

WMO code 4677: **Present weather reported from a manned station.**

```
00 - Cloud development not observed or not observable
```

IV, 4

01 - Cloud generally dissolving or becoming less developed
02 - State of sky on the whole unchanged
03 - Clouds generally forming or developing
04 - Visibility reduced by smoke, e.g. veldt or forest fires, industrial smoke or volcanic ashes
05 - Haze
06 - Widespread dust in suspension in the air, not raised by wind at or near the station at the time of observation
07 - Dust or sand raised by wind at or near the station at the time of observation, but not well-developed dust whirl(s) or sand whirl(s), and no duststorm or sandstorm seen; or, in the case of ships, blowing spray at the station
08 - Well-developed dust or sand whirl(s) seen at or near the station during the preceding hour or at the time of observation, but no dust storm or sandstorm
09 - Duststorm or sandstorm within sight at the time of observation, or at the station during the preceding hour
10 - Mist
11 - Patches of shallow fog or ice fog at the station, whether on land or sea not deeper than about 2 metres on land or 10 metres at sea
12 - More or less continuous shallow fog or ice fog at the station, whether on land or sea, not deeper than about 2m/land or 10m/sea
13 - Lightning visible, or thunder heard
14 - Precipitation within sight, not reaching the ground or the surface of the sea
15 - Precipitation within sight, reaching the ground or the surface of the sea, but distant, i.e. > 5 km from the station
16 - Precipitation within sight, reaching the ground or the surface of the sea, near to, but not at the station
17 - Thunderstorm, but no precipitation at the time of observation
18 - Squalls at or within sight of the station during the preceding hour or at the time of observation
19 - Funnel clouds at or within sight of the station during the preceding hour or at the time of observation
20 - Drizzle (not freezing) or snow grains, not falling as showers, during the preceding hour but not at the time of observation
21 - Rain (not freezing), not falling as showers, during the preceding hour but not at the time of observation
22 - Snow, not falling as showers, during the preceding hour but not at the time of observation
23 - Rain and snow or ice pellets, not falling as showers; during the preceding hour but not at the time of observation
24 - Freezing drizzle or freezing rain; during the preceding hour but not at the time of observation
25 - Shower(s) of rain during the preceding hour but not at the time of observation
26 - Shower(s) of snow, or of rain and snow during the preceding hour but not at the time of observation
27 - Shower(s) of hail, or of rain and hail during the preceding hour but not at the time of observation
28 - Fog or ice fog during the preceding hour but not at the time of observation
29 - Thunderstorm (with or without precipitation) during the preceding hour but not at the time of observation
30 - Slight or moderate duststorm or sandstorm - has decreased during the preceding hour
31 - Slight or moderate duststorm or sandstorm - no appreciable change during the preceding hour
32 - Slight or moderate duststorm or sandstorm - has begun or has increased during the preceding hour
33 - Severe duststorm or sandstorm - has decreased during the preceding hour
34 - Severe duststorm or sandstorm - no appreciable change during the preceding hour
35 - Severe duststorm or sandstorm - has begun or has increased during the preceding hour
36 - Slight/moderate drifting snow - generally low (below eye level)
37 - Heavy drifting snow - generally low (below eye level)
38 - Slight/moderate blowing snow - generally high (above eye level)
39 - Heavy blowing snow - generally high (above eye level)
40 - Fog or ice fog at a a distance at the time of observation, but not at station during the preceding hour, the fog or ice fog extending to a level above that of the observer
41 - Fog or ice fog in patches
42 - Fog/ice fog, sky visible, has become thinner during the preceding hour
43 - Fog/ice fog, sky invisible, has become thinner during the preceding hour
44 - Fog or ice fog, sky visible, no appreciable change during the past hour
45 - Fog or ice fog, sky invisible, no appreciable change during the preceding hour
46 - Fog or ice fog, sky visible, has begun or has become thicker during preceding hour
47 - Fog or ice fog, sky invisible, has begun or has become thicker during the preceding hour
48 - Fog, depositing rime, sky visible
49 - Fog, depositing rime, sky invisible
50 - Drizzle, not freezing, intermittent, slight at time of ob.
51 - Drizzle, not freezing, continuous, slight at time of ob.
52 - Drizzle, not freezing, intermittent, moderate at time of ob.
53 - Drizzle, not freezing, continuous, moderate at time of ob.
54 - Drizzle, not freezing, intermittent, heavy at time of ob.
55 - Drizzle, not freezing, continuous, heavy at time of ob.
56 - Drizzle, freezing, slight
57 - Drizzle, freezing, moderate or heavy (dense)
58 - Rain and drizzle, slight
59 - Rain and drizzle, moderate or heavy
60 - Rain, not freezing, intermittent, slight at time of ob.
61 - Rain, not freezing, continuous, slight at time of ob.
62 - Rain, not freezing, intermittent, moderate at time of ob.
63 - Rain, not freezing, continuous, moderate at time of ob.
64 - Rain, not freezing, intermittent, heavy at time of ob.
65 - Rain, not freezing, continuous, heavy at time of ob.
66 - Rain, freezing, slight
67 - Rain, freezing, moderate or heavy
68 - Rain or drizzle and snow, slight
69 - Rain or drizzle and snow, moderate or heavy
70 - Intermittent fall of snowflakes, slight at time of ob.
71 - Continuous fall of snowflakes, slight at time of ob.
72 - Intermittent fall of snowflakes, moderate at time of ob.
73 - Continuous fall of snowflakes, moderate at time of ob.
74 - Intermittent fall of snowflakes, heavy at time of ob.
75 - Continuous fall of snowflakes, heavy at time of ob.
76 - Diamond dust (with or without fog)
77 - Snow grains (with or without fog)

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78 - Isolated star-like snow crystals (with or without fog)
79 - Ice pellets
80 - Rain shower(s), slight
81 - Rain shower(s), moderate or heavy
82 - Rain shower(s), violent
83 - Shower(s) of rain and snow, slight
84 - Shower(s) of rain and snow, moderate or heavy
85 - Snow shower(s), slight
86 - Snow shower(s), moderate or heavy
87 - Shower(s) of snow pellets or small hail, with or without rain or rain and snow mixed - slight
88 - Shower(s) of snow pellets or small hail, with or without rain or rain and snow mixed - moderate or heavy
89 - Shower(s) of hail, with or without rain or rain and snow mixed, not associated with thunder - slight
90 - Shower(s) of hail, with or without rain or rain and snow mixed, not associated with thunder - moderate or heavy
91 - Slight rain at time of observation - Thunderstorm during the preceding hour but not at time of observation
92 - Moderate or heavy rain at time of observation - Thunderstorm during the preceding hour but not at time of observation
93 - Slight snow, or rain and snow mixed or hail at time of observation - Thunderstorm during the preceding hour but not at time of observation
94 - Moderate or heavy snow, or rain and snow mixed or hail at time of observation - Thunderstorm during the preceding hour but not at time of observation
95 - Thunderstorm, slight or moderate, without hail, but with rain and/or snow at time of observation
96 - Thunderstorm, slight or moderate, with hail at time of ob.
97 - Thunderstorm, heavy, without hail, but with rain and/or snow at time of observation
98 - Thunderstorm combined with dust/sandstorm at time of observation
99 - Thunderstorm, heavy with hail at time of observation

Pressure characteristic over last 3 hours:

*WMO code 0200:***Characteristic of pressure tendency.**

0 - Increasing, then decreasing : atmospheric pressure the same as or higher than 3 hrs ago
1 - Increasing, then steady : atmospheric pressure now higher than 3 hrs ago
2 - Increasing (steadily or unsteadily) : atmospheric pressure now higher than 3 hrs ago
3 - Decreasing or steady, then increasing; or increasing, then increasing more rapidly : atmospheric pressure now higher than 3 hrs ago
4 - Steady : atmospheric pressure the same as 3 hrs ago
5 - Decreasing, then increasing : atmospheric pressure the same as or lower than 3 hrs ago
6 - Decreasing, then steady; or decreasing then decreasing more slowly : atmospheric pressure now lower than 3 hrs ago
7 - Decreasing (steadily or unsteadily) : atmospheric pressure now lower than 3 hrs ago
8 - Steady or increasing, then decreasing; or decreasing, then decreasing more rapidly : atmospheric pressure now lower than 3 hrs ago

Day of Thunder:

6000 NCM table 24

0 - no thunderstorm (0000-2400gmt)
1 - thunderstorm with or without precipitation
9 - no thunderstorm (restricted period)

Day of Hail:

6001 NCM table 23

0 - no hail,ice,etc (0000-2400gmt)
1 - diamond dust
2 - snow grains
3 - snow pellets
4 - ice pellets or small hail (less than 5mm diameter)
5 - hail (diameter 5-9 mm)
6 - hail (diameter 10-19 mm)
7 - hail (diameter 20mm or more)
9 - no hail ,ice etc restricted period

Day of snow or sleet:

6002 NCM table 27

0 - no snow or sleet(0000-2400gmt)
1 - sleet
5 - snow
9 - no snow or sleet(restricted period)

Day of fog:

6003 NCM table 25

0 - visibility 1000m or more at 0900 gmt(previous day)
1 - visibility less than 1000m at 0900 gmt

IV, 6

Day of Gale:

```
6004    NCM table 26

0 - no gale(0000-2400 gmt)
1 - day on which wind speed has reached 34 knots (beaufort force 8) for a
    period of at least 10 minutes
9 - no gale (restricted period)
```

State of concrete:

```
6005    NCM table 22

/ - slab covered by snow or not adequately described by codes 0 to 3
0 - slab dry
1 - slab moist
2 - slab wet
3 - slab icy
```

Snow lying at 0900GMT:

```
6006    CDB flag

0 - no snow or less than half cover of snow lying
1 - more than half cover of snow at 0900z today
```

Snow depth:

```
001 - 1cm
002 - 2cm
... - ...
996 - 996cm
997 - Less than 0.5cm
998 - Snow cover, not continuous
999 - Measurement impossible or inaccurate
```

```
020011 CLOUD AMOUNT

0  0
1  1 OKTA OR <1
2  2 OKTAS
3  3 OKTAS
4  4 OKTAS
5  5 OKTAS
6  6 OKTAS
7  7 OKTAS (<8)
8  8 OKTAS
9  SKY OBSCURED METEOROLOGICAL
10 SKY PARTLY  OBSCURED BY FOG AND/OR OTHER METEOROLOGICAL PHENOMENA
11 SCATTERED
12 BROKEN
13 FEW
```

```
020012 CLOUD TYPE

0  CI
1  CC
2  CS
3  AC
4  AS
5  NS
6  SC
7  ST
8  CU
9  CB
10 NO CH CLOUDS
11 CI FIB (UNC)
12 CI SPI SHEAF
13 CI SPI CUGEN
14 CI UNC/FIB
15 CI VEIL <45'
16 CI VEIL >45'
17 CS WHOLE SKY
18 CS NOT COVER
19 CH MOSTLY CC
20 NO CM CLOUDS
21 AS TR
22 AS OP / NS
23 AC TR LEVEL
24 AC TR PATCHY
25 AC TR BANDS
26 AC CU(CB)GEN
27 AC TR LAYERS
28 AC CAS/FLO
29 AC CHAOTIC
30 NO CL CLOUDS
31 CU HUM/FRA
32 CU MED/CON
33 CU CAL
34 SC CUGEN
35 SC NOT CUGEN
36 SC NEB/FRA
37 ST/CU FRA
38 CU/SC LEVELS
```

IV, 7

```
39 CB CAP
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59 CLOUD INVIS
60 CH INVISIBLE
61 CM INVISIBLE
62 CL INVISIBLE
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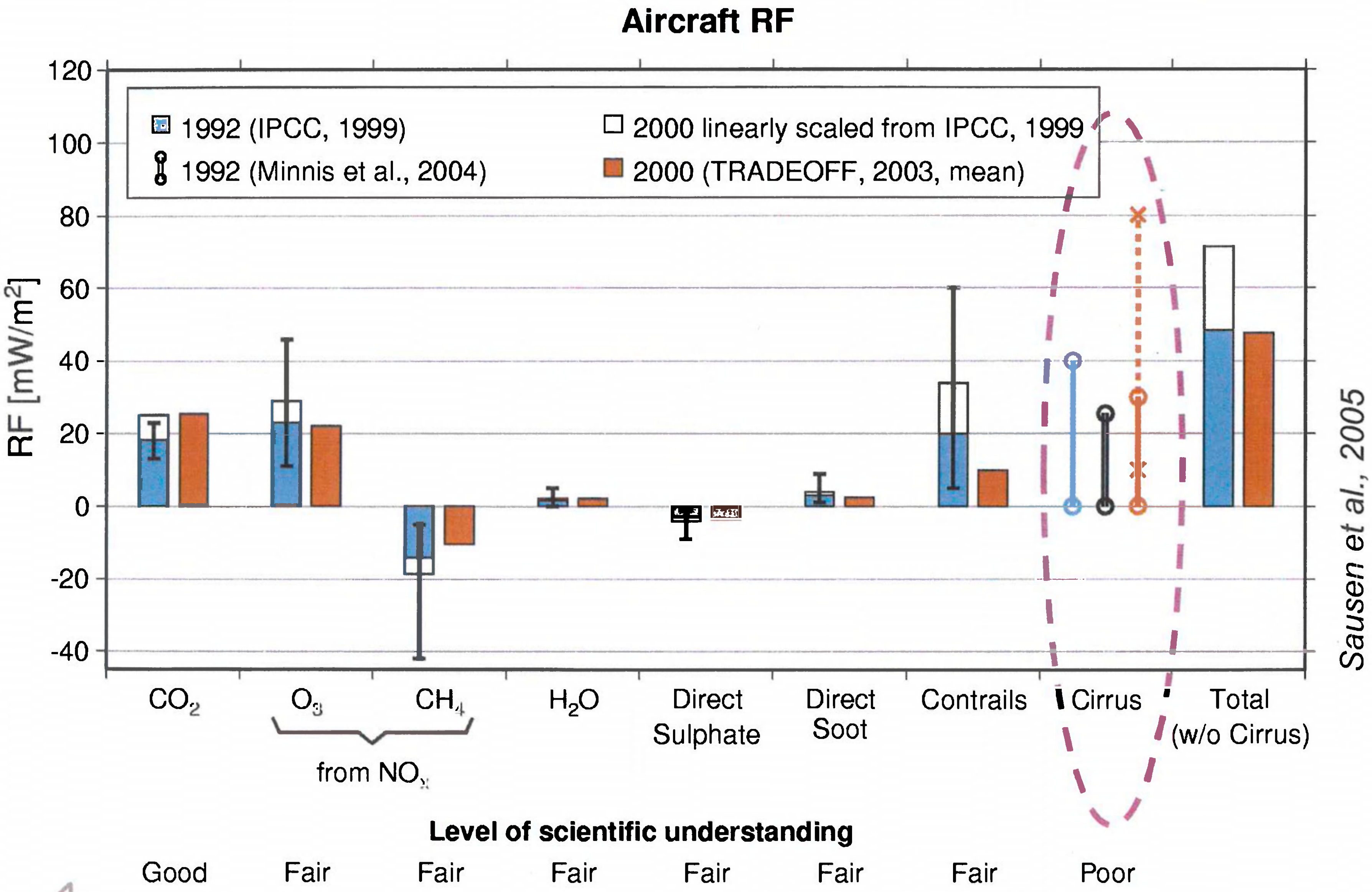
V, 1

APPENDIX 5

Updated Aviation Radiative Forcing for 2000



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VI, 1

APPENDIX 6

VI, 2

Contrails reduce daily temperature range

A brief interval when the skies were clear of jets unmasked an effect on climate.

The potential of condensation trails (contrails) from jet aircraft to affect regional-scale surface temperatures has been debated for years[1–3], but was difficult to verify until an opportunity arose as a result of the three-day grounding of all commercial aircraft in the United States in the aftermath of the terrorist attacks on 11 September 2001. Here we show that there was an anomalous increase in the average diurnal temperature range (that is, the difference between the daytime maximum and night-time minimum temperatures) for the period 11–14 September 2001. Because persisting contrails can reduce the transfer of both incoming solar and outgoing infrared radiation[4,5] and so reduce the daily temperature range, we attribute at least a portion of this anomaly to the absence of contrails over this period.

We analysed maximum and minimum temperature data[6] from about 4,000 weather stations throughout the conterminous United States (the 48 states not including Alaska and Hawaii) for the period 1971–2000, and compared these to the conditions that prevailed during the three-day aircraft-grounding period. All sites were inspected for data quality and adjusted for the time of observation.

Because the grounding period commenced after the minimum temperatures had been reached on the morning of 11 September and ended before maximum temperatures were attained on 14 September (at noon, Eastern Standard Time), we staggered the calculation of the average diurnal temperature range (DTR) across adjacent days (for example, 11 September maxima minus 12 September minima). We repeated this procedure for the three-day periods immediately before and after the grounding period, and also for the same periods (8–11, 11–14 and 14–17 September) for each year from 1971 to 2000.

DTRs for 11–14 September 2001 measured at stations across the United States show an increase of about 1.1 °C over normal 1971–2000 values (Fig. 1). This is in contrast to the adjacent three-day periods, when DTR values were near or below the mean (Fig. 1). DTR departures for the grounding period are, on average, 1.8 °C greater than DTR departures for the two adjacent three-day periods.

This increase in DTR is larger than any during the 11–14 September period for the previous 30 years, and is the only increase greater than 2 standard deviations away from the mean DTR (s.d., 0.85 °C). Moreover, the 11–14 September increase in DTR

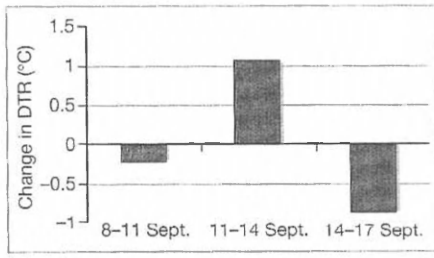

Figure 1 Departure of average diurnal temperature ranges (DTRs) from the normal values derived from 1971–2000 climatology data for the indicated three-day periods in September 2001. These periods included the three days before the terrorist attacks of 11 September; the three days immediately afterwards, when aircraft were grounded and there were therefore no contrails; and the subsequent three days.

was more than twice the national average for regions of the United States where contrail coverage has previously been reported to be most abundant (such as the midwest, northeast and northwest regions)[7].

Day-to-day changes in synoptic atmospheric conditions can affect regional DTRs[8]. In particular, a lack of cloud cover helps to increase the maximum (and reduce the minimum) temperature. Maps of the daily average outgoing long-wave radiation (OLR)[9,10] — a proxy for optically thick clouds — show reduced cloudiness (that is, larger OLR) over the eastern half of the United States on 11 September, but more cloud (smaller OLR) over parts of the west. Cloud cover subsequently decreased in the west and increased over much of the eastern half of the country during the next two days, producing predominantly negative three-day OLR changes in the east and positive values in parts of the west.

Our findings indicate that the diurnal temperature range averaged across the United States was increased during the aircraft-grounding period, despite large variations in the amount of cloud associated with mobile

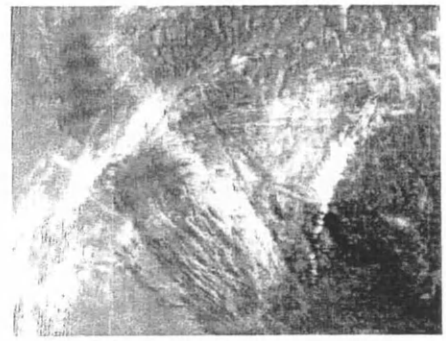

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Figure 2 Flight lines: jet contrails can clearly be seen as thin streaks in this satellite image of the southwestern United States.

weather systems (Fig. 2). We argue that the absence of contrails was responsible for the difference between a period of above-normal but unremarkable DTR and the anomalous conditions that were recorded.

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1. Changnon, S. A. *J. Appl. Meteorol.* 20, 496–508 (1981).
2. Travis, D. J. & Changnon, S. A. *J. Weather Modification* 29, 74–83 (1997).
3. Sassen, K. *Bull. Am. Meteorol. Soc.* 78, 1885–1903 (1997).
4. Duda, D. P., Minnis, P. & Nguyen, L. *J. Geophys. Res.* 106, 4927–4937 (2001).
5. Meerkotter, R. *et al. Ann. Geophys.* 17, 1080–1094 (1999).
6. National Oceanic and Atmospheric Administration. *TD3200/3210 Data Set for 1971–2001* (Natl Climate Data Center, Asheville, North Carolina, 2001).
7. DeGrand, J. Q., Carleton, A. M., Travis, D. J. & Lamb, P. J. *Appl. Meteorol.* 39, 1434–1459 (2000).
8. Karl, T. R. *et al. Bull Am. Meteorol. Soc.* 74, 1007–1023 (1993).
9. Liebmann, B. & Smith, C. A. *Bull Am. Meteorol. Soc.* 77, 1275–1277 (1996).
10. http://www.cdc.noaa.gov (NOAA-CIRES Climate Diagnostics Center, Boulder, Colorado, USA).

Competing financial interests: declared none.

Animal behaviour

Male parenting of New Guinea froglets

Male parental care is exceptionally rare in nature, although one of the most fascinating aspects of New Guinea's biodiversity is the evolution of male care in the frog family Microhylidae[1]. Here I report a new mode of parental care: transport of froglets by the male parent, which was recently discovered in two species of microhylid frogs from the mountains of Papua New Guinea. As the offspring jump off at different points, they may benefit from reduced competition for food, lower predation pressure and fewer opportunities for inbreeding between froglets, which may explain why this unusual form of parental care evolved.

I quantified the parental care behaviour of several species of microhylid frog at the Crater Mountain Biological Research Station, Chimbu Province, Papua New Guinea (6° 43′ S, 145° 05′ E), which is located on the largest tropical island in

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Regional Variations in U.S. Diurnal Temperature Range for the 11–14 September 2001 Aircraft Groundings: Evidence of Jet Contrail Influence on Climate

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ABSTRACT

The grounding of all commercial aircraft within U.S. airspace for the 3-day period following the 11 September 2001 terrorist attacks provides a unique opportunity to study the potential role of jet aircraft contrails in climate. Contrails are most similar to natural cirrus clouds due to their high altitude and strong ability to efficiently reduce outgoing infrared radiation. However, they typically have a higher albedo than cirrus; thus, they are better at reducing the surface receipt of incoming solar radiation. These contrail characteristics potentially suppress the diurnal temperature range (DTR) when contrail coverage is both widespread and relatively long lasting over a specific region. During the 11–14 September 2001 grounding period natural clouds and contrails were noticeably absent on high-resolution satellite imagery across the regions that typically receive abundant contrail coverage. A previous analysis of temperature data for the grounding period reported an anomalous increase in the U.S.-averaged, 3-day DTR value. Here, the spatial variation of the DTR anomalies as well as the separate contributions from the maximum and minimum temperature departures are analyzed. These analyses are undertaken to better evaluate the role of jet contrail absence and synoptic weather patterns during the grounding period on the DTR anomalies.

It is shown that the largest DTR increases occurred in regions where contrail coverage is typically most prevalent during the fall season (from satellite-based contrail observations for the 1977–79 and 2000–01 periods). These DTR increases occurred even in those areas reporting positive departures of tropospheric humidity, which may reduce DTR, during the grounding period. Also, there was an asymmetric departure from the normal maximum and minimum temperatures suggesting that daytime temperatures responded more to contrail absence than did nighttime temperatures, which responded more to synoptic conditions. The application of a statistical model that "retro-predicts" contrail-favored areas (CFAs) on the basis of upper-tropospheric meteorological conditions existing during the grounding period, supports the role of contrail absence in the surface temperature anomalies; especially for the western United States. Along with previous studies comparing surface climate data at stations beneath major flight paths with those farther away, the regionalization of the DTR anomalies during the September 2001 "control" period implies that contrails have been helping to decrease DTR in areas where they are most abundant, at least during the early fall season.

1. Introduction

An important consideration in identifying the climate impacts of changes in cloud radiative forcing are the role of high clouds, including the "false cirrus" condensation trails (contrails) generated by jet aircraft. Contrails may persist as "outbreaks" on multihour (3–6 h) time scales and over space scales of more than 1000 km^2 (Travis et al. 1997; Penner et al. 1999; Minnis et al. 2002). These contrail outbreaks may obscure a substantial portion of the sky or mix with "natural" cirrus to enhance the total cloud amount (Bakan et al. 1994; Travis et al. 1997; Duda et al. 2001; Fig. 1). Hence, the radiative forcing produced by contrails may be significant for those regions of the United States characterized by many such outbreaks (e.g., the Midwest, parts of the West Coast, the Northeast and Southeast; Minnis et al. 1997; Sassen 1997; DeGrand et al. 2000).

Some researchers have speculated that persisting contrails exacerbate "global warming" in areas where they

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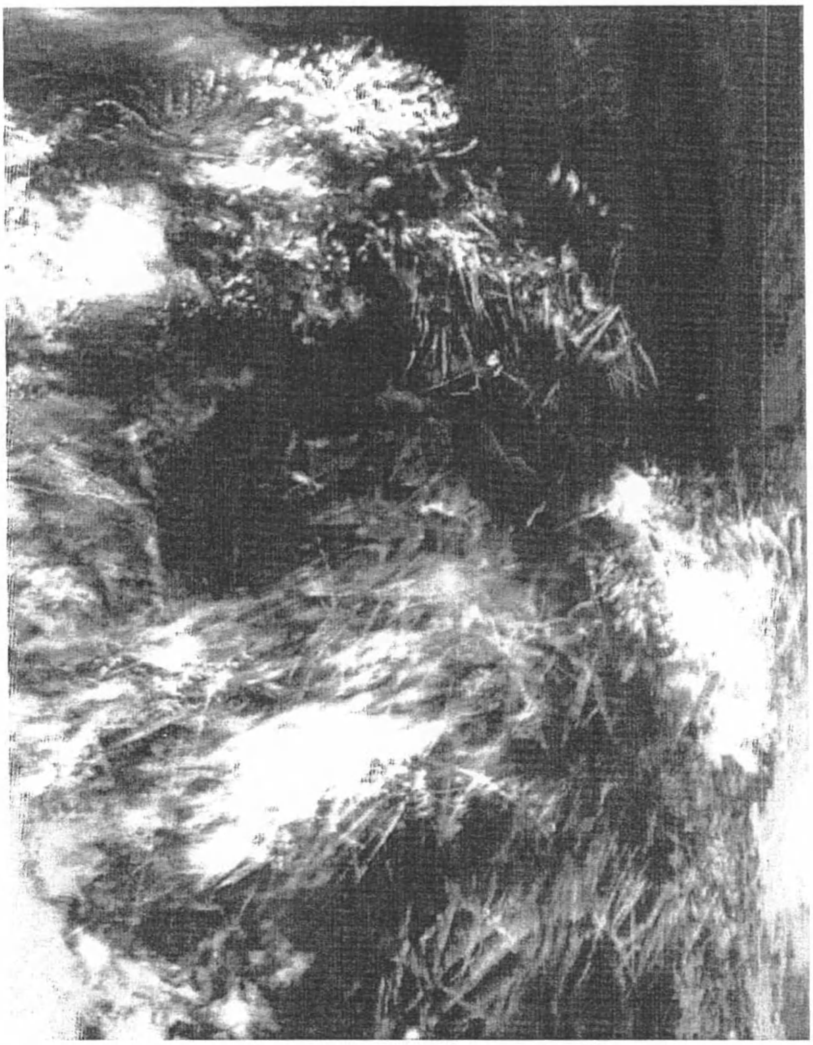

FIG. 1. AVHRR thermal IR (band 4) image (at 1.1-km resolution) of a contrail "outbreak" over the Midwest taken at 1000 UTC 11 Sep 1995. The southern tip of Lake Michigan can be seen at the top of the image.

most frequently occur, due to their ability to reduce outgoing infrared radiation while transmitting some solar radiation to the surface; similar to natural cirrus (e.g., Meerkotter et al. 1999). However, there is probably a diurnal dependence to the role of contrails in radiative forcing that is missing in the case of natural cirrus, and that is enhanced by the strong diurnal variability of aircraft flight frequencies. Because contrails contain a higher density of relatively small ice crystals compared with natural cirrus clouds (Murcray 1970; Gothe and Grassl 1993), the contrail radiative forcing during daylight hours may be dominated by the higher albedo of contrails versus natural cirrus, leading to a potential surface "cooling" (Mims and Travis 1997). At night, the infrared forcing of contrails dominates relative to clear-sky conditions, producing a surface "warming" effect similar to natural clouds. Thus, when considered across a 24-h period it is possible that the net contrail radiative forcing is relatively small. However, the combination of both the daytime cooling and nighttime warming effects should result in a decrease in the diurnal temperature range (DTR), as shown in previous case studies (e.g., Travis and Changnon 1997; Travis et al. 2002). Thus, a need exists to investigate the net effect of contrails on surface temperature across a range of geographic regions and synoptic conditions, especially because significant decreases in DTR have been reported for some areas of the United States during the second half of the twentieth century, including those where contrails are most abundant (e.g., Karl et al. 1993; Travis and Changnon 1997).

Previous attempts to identify a contrail effect in the

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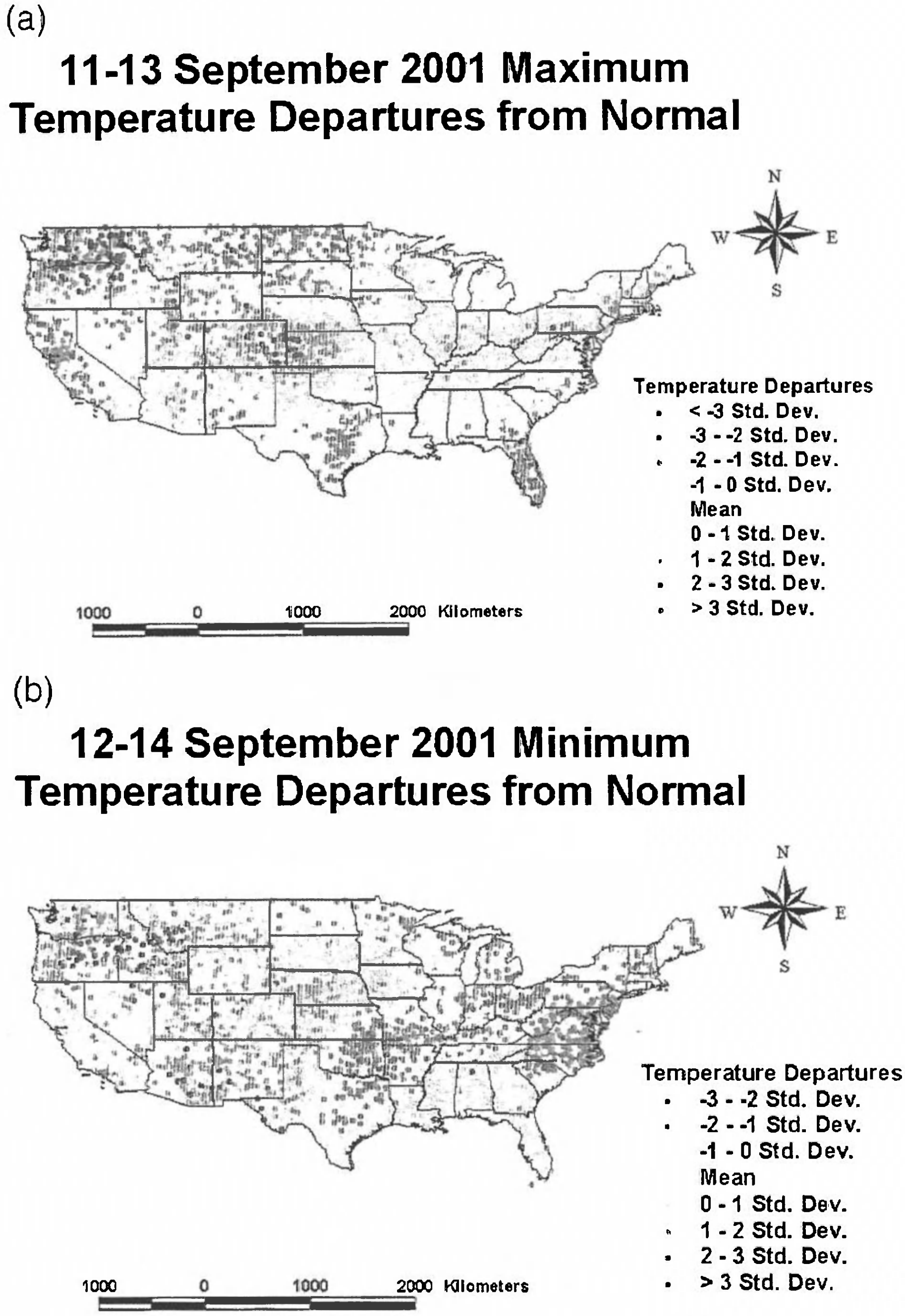

FIG. 2. Map of weather station std dev departures from normal of (a) 11–13 Sep 2001 max temperature (T_{max}), and (b) 12–14 Sep 2001 min temperature (T_{min}).

climate record have been based mostly on circumstantial evidence: from comparisons of locations with high frequencies of jet aircraft flights or contrails to adjacent locations having fewer (Changnon 1981; Travis and Changnon 1997; Allard 1997). Accordingly, it has been difficult to quantify a contrail effect because of the lack of a comparison "control" period during which persisting contrails were absent significantly longer than their typical life span. The grounding of all commercial aviation in U.S. airspace for approximately 72 h between 11 and 14 September 2001 that followed the terrorist hijackings of four jetliners in U.S. airspace pro-

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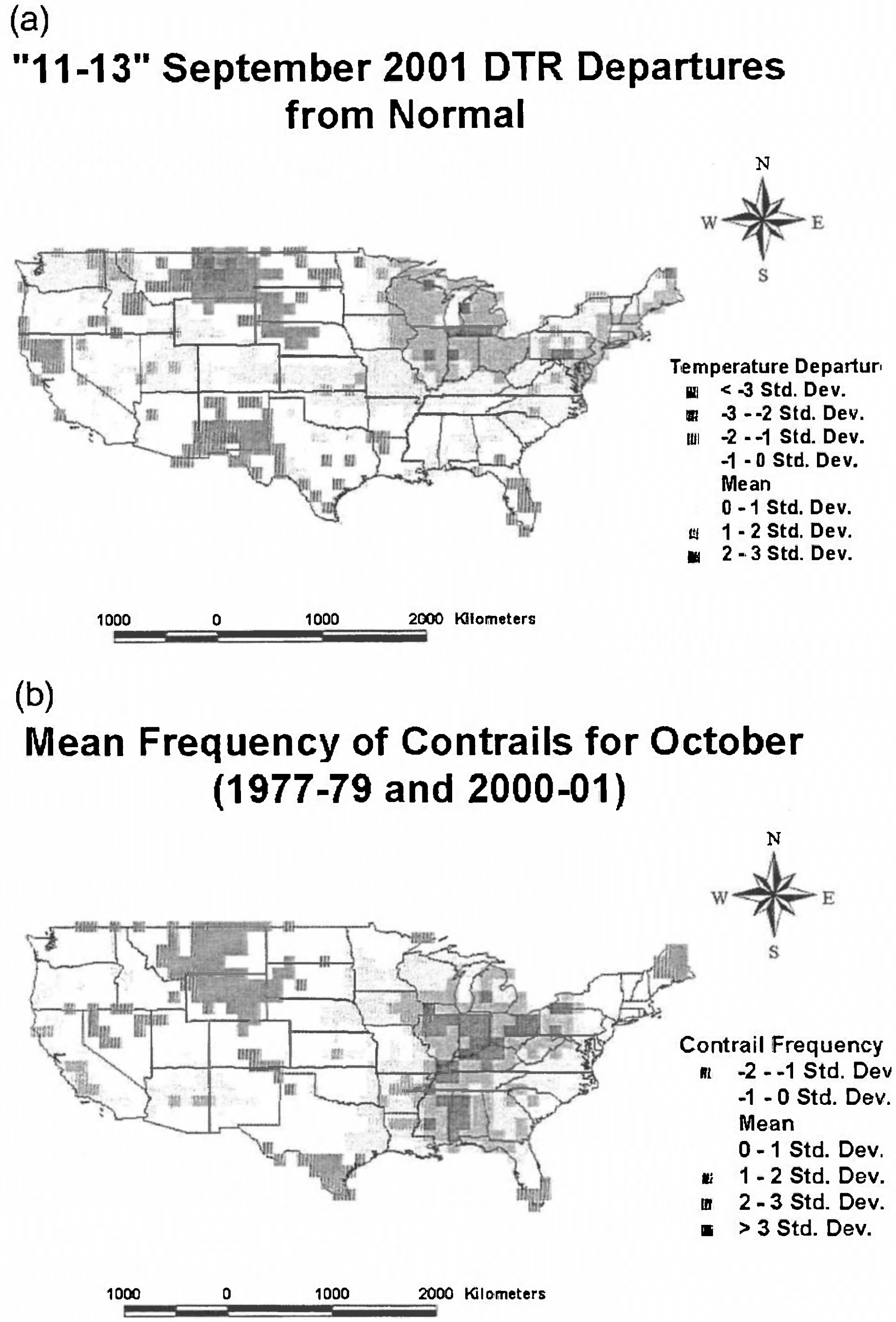

FIG. 3. Map of 1° × 1° resolution (a) grid cell–averaged DTR std dev departure values from long-term (1971–2000) normals for 11–13 Sep 2001, and (b) the combined 1977–79 and 2000–01 mean contrail frequency for Oct.

vides an unexpected opportunity to investigate the regional-scale as well as U.S.-wide effects of contrails on DTR. Our previous study (Travis et al. 2002) has shown that the U.S.-averaged DTR departure for the grounding period increased by approximately 1°C compared to the long-term normals (1971–2000), and 1.8°C compared to the average departure of the adjacent 3-day periods.

To evaluate the presence and magnitude of U.S. re-

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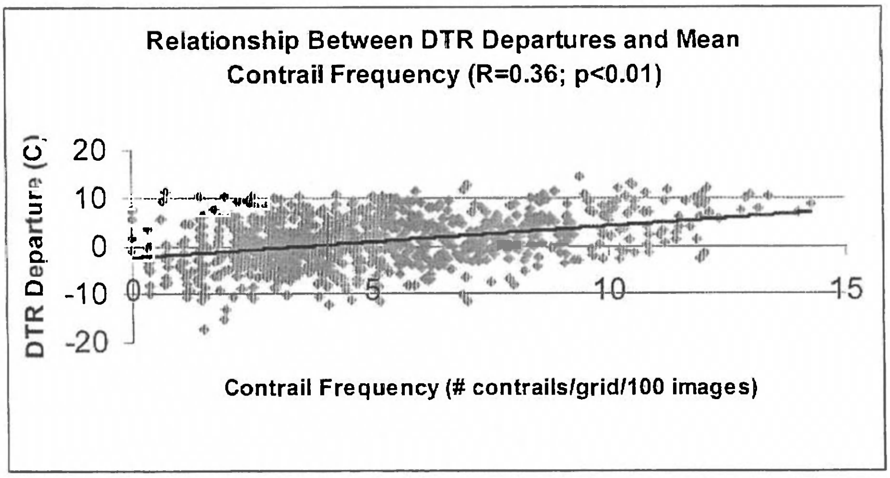

FIG. 4. Scatterplot of the relationship between 11–13 Sep 2001 DTR departures and mean combined 1977–79 and 2000–01 contrail frequency for Oct (R = 0.36; $p < 0.01$).

gional-scale DTR anomalies during the grounding period, and determine any associations with the frequency of contrail coverage typically experienced during the fall season, we utilize combinations of surface temperature observations, high-resolution satellite data, and synoptic-scale meteorological reanalyses. Moreover, we provide evidence linking the lack of jet contrails during the grounding period to most observed increases in regional DTR, and also to the asymmetric changes in maximum and minimum temperatures from which DTR is derived.

2. Data and methods

a. Station temperature data

Station data on the daily maximum temperature (T_{max}) and minimum temperature (T_{min}) for all first-order, automated, and cooperative stations in the United States, were obtained from the National Climate Data Center (NCDC 2003) for the most recent 30-yr "normals" period (1971–2000), plus 2001 for the grounding period. Although daily normals were available for a total of 5556 stations, data for only 5404 of those stations were available for the 2001 study period. In addition, many of the stations were cooperative observing sites that record maximum and minimum temperatures from only one observation per 24-h period, unlike the remaining first- and second-order stations that compute daily maxima and minima from continuous observations starting after midnight each day. Thus, it was necessary to standardize the cooperative data by observing time. To ensure that the daily maxima and minima for 11–14 September 2001 were assigned to the correct day, we only included those stations that recorded observations between 0700–0900 or after 1600 local time (LT). When observations were recorded between 0700 and 0900 LT the T_{max} value was assumed to represent the value for the previous day, and when observed after 1600 LT, for the current day. Because only observations from 0700 LT and later were included, each daily T_{min} was assumed to represent the current day's value. These standardization efforts still allowed 4233 stations to be utilized in the temperature analyses, with a reasonably even distribution across the United States (Fig. 2).

Because the aircraft-grounding period began during midmorning (eastern standard time) on 11 September and ended around noon on 14 September,[1] it was necessary to stagger the calculations of average T_{max}, T_{min}, and DTR across adjacent days. Thus, the afternoon of 11 September and the morning of 14 September represent the beginning and end periods, respectively, of the analysis. The average T_{max} was calculated as the mean of all such observations for 11–13 September (Fig. 2a) and the mean T_{min} was calculated as the average of all such observations for 12–14 September (Fig. 2b). The DTR values for "11 September" were calculated by subtracting each station's minimum temperature on 12 September from its maximum on 11 September, and similarly for the rest of the grounding period. The DTR values so calculated were then averaged for the "11–13" September 2001 period. To evaluate DTR values for the 3-day grounding period in context of the contemporary climatology, we calculated DTR in a similar way for each 11–13 September period for 1971–2000; thus, providing long-term station DTR normals (NCDC 2003). DTR departures for 11–13 September 2001 were then calculated by subtracting station values for 2001 from the corresponding 1971–2000 normals.

[1] A relatively small number of short flights (approximately 4000) took place during the evening of 13 September to reposition aircraft that were redirected during the shutdown on the morning of 11 September. These should not affect the conclusions of this study.

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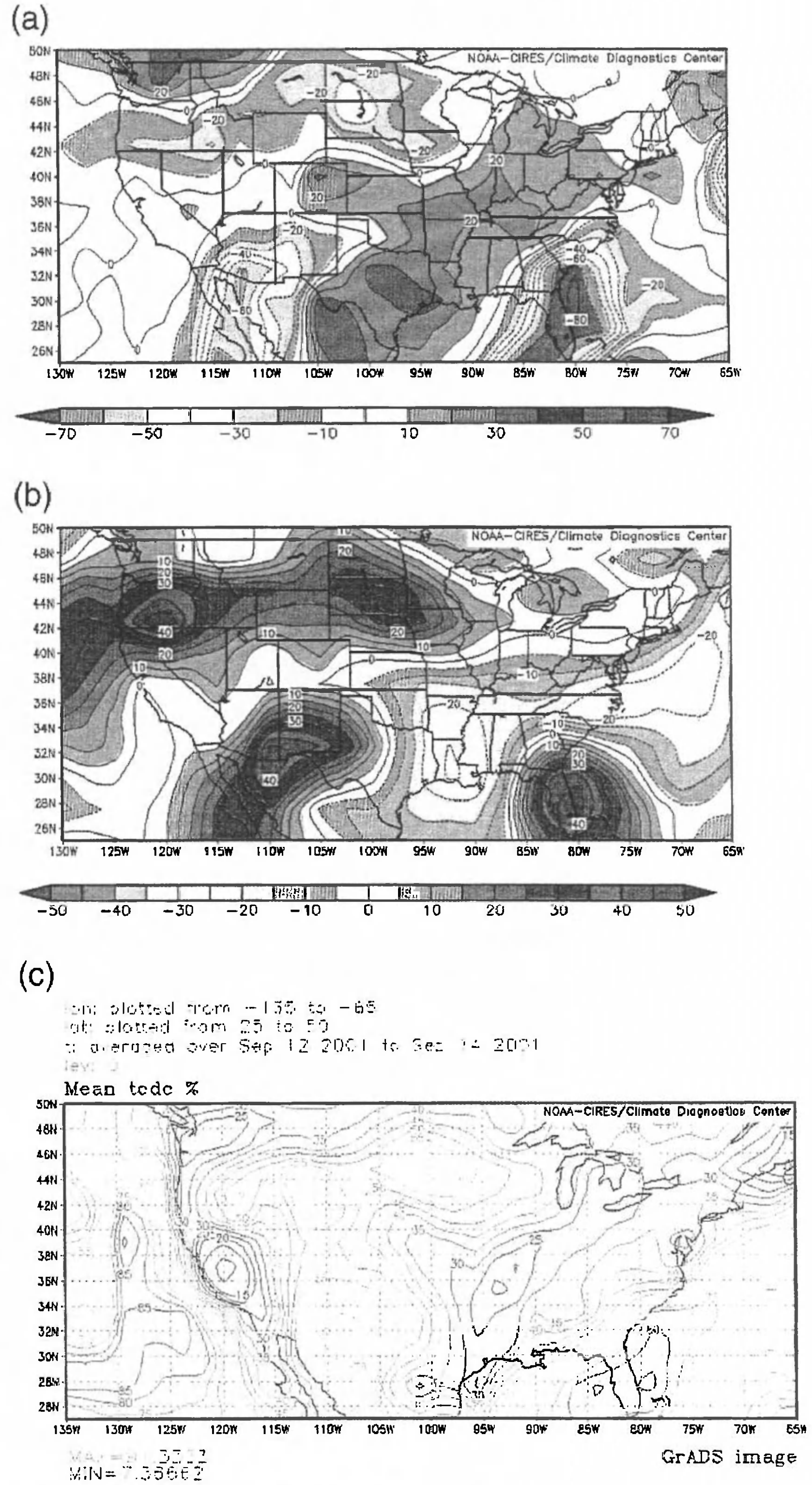

FIG. 5. Mapped 3-day average (12–14 Sep 2001) of (a) anomalies of OLR in W m^{-2}, (b) anomalies of relative humidity at 500 hPa; RH(500) in percent; and (c) mean percentage of total cloud sky coverage, derived using the NCEP–NCAR reanalyses.

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b. Satellite data on contrail outbreaks

To best represent the variations in frequency and density of "typical" contrail coverage across the United States during the fall season for both the recent historical and contemporary periods, we combined two satellite-based data sources of contrail frequency: one previously published and the other original. The first was an analysis of contrail frequency over the conterminous United States for the 1977–79 period based on manual interpretation of high-resolution (0.6 km) Defense Meteorological Satellite Program (DMSP) satellite imagery (DeGrand et al. 2000). This study determined the frequency of contrail occurrence per 1° × 1° grid cells for each of the four midseason months. October was the closest month to our study period and provides an approximation of contrail frequency for the fall season (DeGrand et al. 2000). The procedures used in the recent historical contrail study were duplicated here for the months of October 2000 and 2001, to estimate contrail frequency for the contemporary fall season period. The only exception to this was the satellite data source. For 2000–01, the nonavailability of a dataset having identical temporal and spatial resolutions to the DMSP imagery necessitated that we use data from the Advanced Very High Resolution Radiometer (AVHRR). The AVHRR has a slightly coarser nadir resolution (1.1 km) yet comparable temporal and spatial coverage to that of the DSMP for the 1977–79 period. The slight decrease in resolution of the AVHRR compared with the DMSP should have only a small impact on the ability to recognize *single* contrails (Detwiler and Pratt 1984). More importantly, from the climatic perspective, our use of AVHRR should not substantially impact the relative frequency of regional contrail coverage (i.e., that due to multiple contrails occurring simultaneously). An average of four images per day were analyzed across the two study periods to approximate the regional variations in mean contrail frequency during the climate normals and 2001 periods. The locations of each contrail were stored in a geographic information system (GIS) database [Environmental Systems Research Inc., (ESRI) 1999] for subsequent manipulation and statistical analyses.

Contrails are best distinguished from natural clouds using the infrared band 4 of the AVHRR that is present on all of the National Oceanic and Atmospheric Administration (NOAA) polar-orbiting satellites. We followed the manual pattern recognition method described in Carleton and Lamb (1986) and DeGrand et al. (2000). This method identifies contrails as linear cloud features that are oriented in random directions, unlike natural high clouds, which typically follow the prevailing synoptic flow of the upper troposphere (e.g., Fig. 1). We obtained the contrail dataset for the recent historical period and combined it with our contemporary data to produce mean 1° × 1° resolution contrail frequencies for the conterminous United States.

To permit statistical analyses comparing DTR departures with these satellite-based contrail data it was also necessary to convert all of the point-location weather station observations into grid-averaged (1° × 1°) values. This was accomplished using the same contrail grid GIS database, and spatially associating the location of each grid cell with the underlying weather stations. We then calculated the average temperature values for all weather stations within each cell. The U.S.-averaged number of stations per grid cell was 3.2. When no weather stations existed in a particular grid cell (for 26 of 900 total grids) the grid value was interpolated from the four adjacent grid values. If four adjacent grid values were not available (e.g., along international border and coastal regions) the grid was not included in any further analysis. This procedure resulted in a total of 882 grid cells (98%), containing both fall season contrail frequencies and 11–13 September DTR anomalies, to test the hypothesis that an association existed between the two.

c. Analysis of synoptic weather conditions

To more definitively link the regional DTR anomalies with the absence of jet contrails during the grounding period, it is necessary to evaluate the synoptic weather conditions occurring over the conterminous United States. For example, a stagnant weather pattern with anomalously dry air (i.e., low humidity, lack of optically thick clouds) over a large region of the United States for the greater part of the 3-day period, could provide an alternative explanation for the observed anomalous increases in U.S.-averaged DTR (Travis et al. 2002). We used the National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP–NCAR) reanalysis daily-averaged data on top-of-the-atmosphere outgoing longwave radiation (OLR) as a surrogate for cloud cover, and 500-hPa relative humidity to depict tropospheric moisture for the grounding period [NOAA–CIRES (Cooperative Institute for Research in Environmental Sciences) 2002]. We computed the 3-day-averaged departure of each parameter for the grounding period (12–14 September) from its corresponding climatological normal. These were compared to the maps of DTR and T_{max} and T_{min} for the same period for visual associations.

d. Application of a contrail outbreak "retro-prediction" method

It is instructive to estimate where contrails likely would have occurred if commercial aircraft flights had continued as normal for the 11–13 September period. For this purpose we developed a "retro-prediction" (retrodiction) statistical method for contrail outbreaks occurring in otherwise clear air. The retrodiction method uses statistical composites (i.e., ensemble averages and variances) of the upper-tropospheric (300, 250, 200 hPa)

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meteorological conditions associated with 48 outbreaks that occurred over the conterminous United States during the 8–16 September periods of 1995–97 and 1999–2001 (the calibration period). Data on meteorological parameters (temperature, humidity, vertical wind shear, vertical motion) previously shown (e.g., Appleman 1953; Schrader 1997; Travis 1996; Travis et al. 1997; Chlond 1998; Kastner et al. 1999) to influence the formation likelihood and persistence time of contrails, were acquired for each outbreak using the 6-hourly NCEP–NCAR reanalyses (Kistler et al. 2001). The outbreak data were then expressed as anomalies from the long-term means for each variable, pressure level, and location, and averaged to yield the composites. For the calibration period, the following outbreak meteorological variables/tropospheric levels were statistically different from climatology: increased values of humidity at 300 hPa (RH range = +7.5%–+58.0%), lower temperature and reduced Z_{300}–Z_{200} thickness (−6.5 m), light easterly u-wind anomalies at 250 hPa (range = −2.2 to −2.9 m s^{-1}), and slightly negative (i.e., upward) vertical motion (mean = -0.54×10^{-3} Pa s^{-1} at 250 hPa). Using GIS, we applied the outbreak composite statistical ranges to two independent sets of reanalyses "test" periods: 8–16 September 1998, and the day immediately preceding, and also immediately following the grounding period. The AVHRR imagery for these periods was also inspected for contrail outbreaks. Using a test criterion of a minimum of 50% spatial overlap between the retrodicted and observed contrail outbreaks, we found good agreement (25 out of the 30 cases). This allowed us confidently to apply the method to the upper-tropospheric reanalyses for the grounding period. The resulting contrail-favored areas (CFAs) mapped locations, and their associations with DTR departures, are discussed in section 3d.

3. Results and discussion

a. T_{max} and T_{min} spatial trends

Although both the 3-day U.S.-averaged T_{max} and T_{min} were warmer than normal for the grounding period, the T_{min} increase (0.3°C) was about one-fourth that of T_{max} (1.2°C). This asymmetric variation from the long-term means may indicate that the lack of contrails impacted the daytime temperatures more than those at night. Such a possibility accords with the observed greater frequencies of contrails during daytime versus nighttime hours, in association with diurnal differences in the frequencies of jet aircraft flights (Bakan et al. 1994; Minnis et al. 1997).

The spatial patterns of T_{max} for 11–13 September 2001 (Fig. 2a) show strongest increases in the Intermountain West and Pacific Northwest, extending through the Midwest and into the northeast United States. Strongest decreases of T_{max} occurred in California, the northern Great Plains, the Southwest, and Florida. For T_{min} (Fig. 2b) the largest increases were in the West (except California) and the Gulf Coast states. The largest combined increase of T_{max} and T_{min} occurred in portions of the Northwest. This can be partially attributed to a persistent southerly flow that was produced from synoptic-scale circulations associated with a storm system centered off the northern California coast for much of the grounding period. This storm also likely contributed to the large decrease in T_{max} seen in northern California due to extensive daytime cloud coverage. Strong decreases in T_{min} occurred through the southern Great Plains, Midwest and Great Lakes, the Mid-Atlantic region, and the northeast United States. Possible associations between these spatial variations of T_{max} and T_{min} departures, and the lack of contrails during the grounding period, are discussed in section 3c.

b. DTR spatial trends and associations with contrail frequency

The spatial variation of the grid-averaged DTR anomalies for the grounding period (Fig. 3a) shows that the largest positive departures extended across portions of the central and northeast United States as well as the Pacific Northwest. Because these regions have previously been reported (Minnis et al. 1997; DeGrand et al. 2000) as being climatologically favorable for outbreaks of persisting contrails, we argue that this anomalous increase was associated with the absence of contrails during the aircraft groundings (Travis et al. 2002), in combination with synoptic conditions.

To identify the relationship between the regional DTR increases of the grounding period and spatial variations in the typical fall-season contrail coverage, Fig. 3b summarizes the mean contrail frequency (combined 1977–79, 2000–01) averaged for the same 1° × 1° grids as the DTR data. The frequency pattern of contrails for this period appears broadly similar to that shown in previous studies for other times of the year (Minnis et al. 1997; DeGrand et al. 2000), with the contrail frequency maxima occurring in the Midwest, Southeast, and parts of the West.

Visual comparison of Figs. 3a and 3b suggests some agreement between those regions having the largest increases in DTR during the grounding period and those typically experiencing the greatest contrail coverage during the fall season. To quantify the presence and strength of this relationship a Pearson correlation coefficient was calculated between DTR departure and contrail frequency for the 882 grids available for analysis (Fig. 4). The statistically significant positive relationship ($R = 0.36$; $p < 0.01$) supports our contention that a contrail-induced suppression of DTR was present in the 1971–2000 normals throughout much of the United States, and especially in areas where contrails are typically most prevalent. Moreover, the gradual reduction in statistical scatter about the trend line as contrail frequency increases may indicate that the contrail "sig-

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nal" in DTR departure was more distinguishable from synoptic-scale "background" influences for those grids having the highest mean contrail frequency.

c. *Synoptic variations in cloud and humidity during the grounding period*

The 3-day average (12–14 September 2001) OLR anomaly map (Fig. 5a) shows positive departures (i.e., fewer clouds or lower mean cloud-top altitude) in a swath extending from the south-central United States through the Midwest and into the mid-Atlantic regions. A smaller area of OLR positive departures also occurred in the Pacific Northwest. In contrast, OLR negative departures (i.e., more clouds or higher mean cloud-top altitude) occurred over the Southwest, Florida, and the extreme southeast United States, and parts of the Intermountain West extending through the northern Great Plains. The remainder of the country had close to normal departures of OLR for the grounding period. A comparison of the OLR anomaly field with that of the midtropospheric (500 hPa) relative humidity [RH(500); Fig. 5b], shows general consistency: areas of positive (negative) relative humidity departure accompany increased moisture and ascent of air (decreased moisture and subsidence), and tend to be associated with negative (positive) anomalies of OLR (Fig. 5a). Thus, about one-half of the United States experienced fewer or lower-altitude clouds than normal during the grounding period; the other half had either near-normal or more than normal/deeper clouds. This statement is supported by the analysis of the mean percentage of total cloud coverage (TCDC; departures not available) for the grounding period (Fig. 5c), which shows good agreement with the OLR departures in most areas of the United States. Stratifying the 3-day averaged RH(500) into daytime and nighttime components (Fig. 6) also shows strong spatial consistency and reduces the possibility that the asymmetrical departures of T_{max} and T_{min} reported in section 3a are a result of large diurnal variations in relative humidity.

It is particularly interesting that some of the largest DTR and T_{max} anomalies in the Intermountain West occurred near the outer edges of the areas having the most positive anomalies of humidity and deepest cloud cover (i.e., Colorado, Utah; Fig. 5). The lack of clouds in the adjacent areas suggests that although moisture levels were above normal (Fig. 5b), they were not sufficient for substantial cloud coverage to form through natural processes. However, because such environments are often conducive to contrail formation [i.e., high humidity but few clouds; Travis et al. (1997); section 3d], it is reasonable to assume that contrails likely would have formed in these areas had airplanes been flying. This implies that the lack of contrails in those areas helped offset the tendency for DTR to decrease when averaged over the 3-day grounding period. Such a possibility is now evaluated using the CFA retrodictions for the same period.

d. *Retrodicted contrail outbreaks and associations with DTR anomalies*

Figure 7 depicts the grounding-period CFAs derived from the contrail-outbreak retrodiction method (section 2d). To facilitate visual comparisons with the DTR departure map (Fig. 3a), the CFAs were converted to $1° \times 1°$ grids for locations where contrail occurrence was favorable for a minimum of at least 12 h during the grounding period ("moderate susceptibility"). Grid cells over which CFAs existed for more than 50% of the grounding period (i.e., 36 h) were deemed to have "high susceptibility." All remaining grid cells were designated as having "low susceptibility" (Fig. 7). The Pacific Northwest, Intermountain West, and Southwest U.S. regions were highly susceptible to contrails during the grounding period (Fig. 7). Smaller regions of contrail high susceptibility included the Midwest, Great Lakes, and Florida. These high susceptibility CFAs coincide with the edges of the positive moisture anomaly areas (Fig. 5b). Such a result concurs well with previous research on contrail–synoptic weather associations, which has reported that contrails occur most commonly along the leading edge of cirrus shields associated with frontal cyclones and convective storms (Detwiler and Pratt 1984; Travis et al. 1997; DeGrand et al. 2000).

A visual comparison of the departure maps for T_{max} and T_{min} (Figs. 2a,b) with Figs. 5 and 7 suggests that T_{max} shows a closer association with the CFA high susceptibility retrodiction (except for Florida), whereas T_{min} shows a closer association with the synoptics; specifically, OLR and total cloud cover. This may imply that the lack of contrails affected T_{max} more than T_{min} during the grounding period, especially in the West. There, the combination of a warm, moist southerly flow and the lack of airplanes led to increasing humidity and temperature but less cloud coverage than otherwise would have occurred from contrail formation; especially during the daytime when air traffic would normally have been greatest (with less impact on T_{max}). In the eastern half of the United States, the increased DTR seems to have resulted from a combination of dry air and lack of clouds (lowers T_{min}, raises T_{max} and DTR) and the lack of contrails. This is consistent with the observation (section 3a) that the U.S.-averaged T_{max} increased more than T_{min} during the grounding period.

Comparing Fig. 7 with the DTR departure map (Fig. 3a) shows strong agreement for much of the west, especially in the Intermountain and Northwest regions. For the entire conterminous United States the average DTR departure for the high susceptibility grid cells (+1.3°C) is statistically greater ($p < 0.01$) than that for the moderate susceptibility (+0.9°C) and the low susceptibility grid cells (+0.8°C). The slightly higher av-

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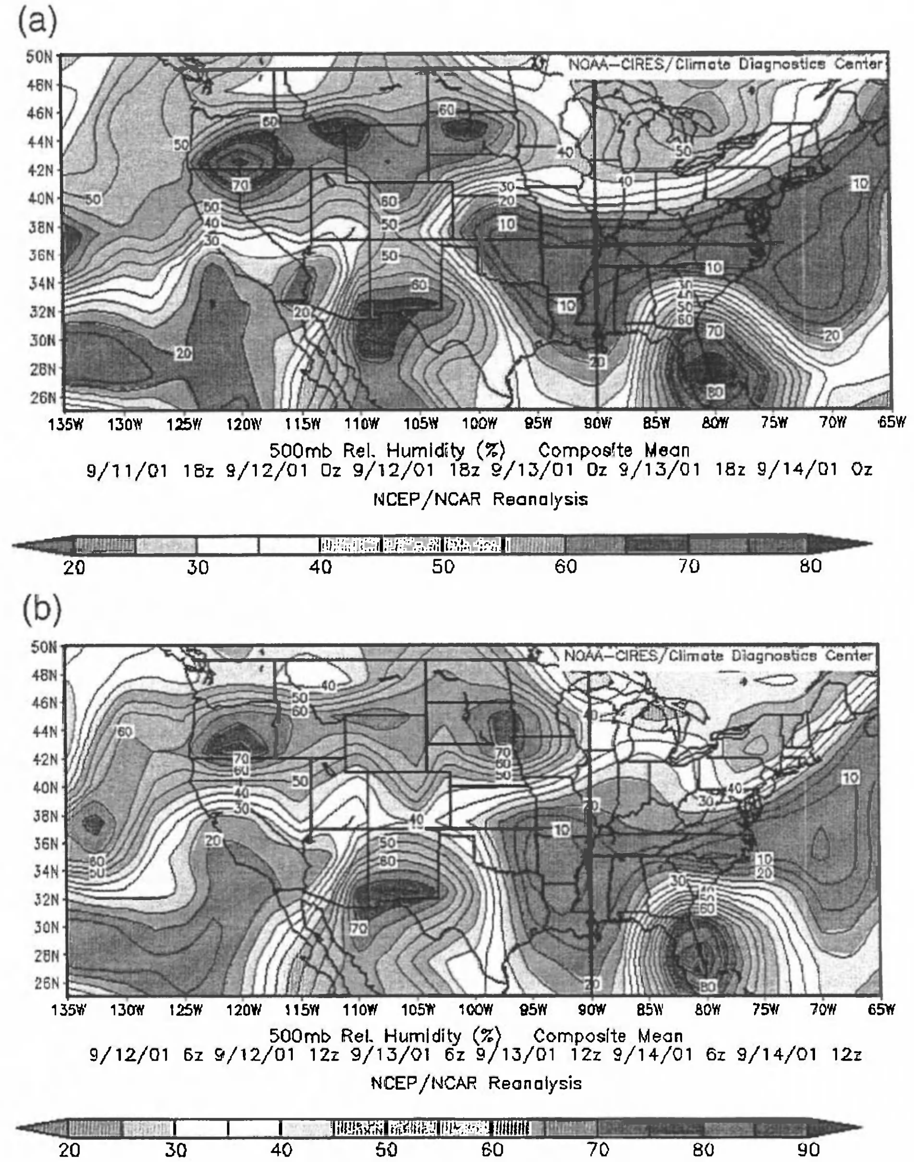

FIG. 6. Mapped 3-day average (1800 UTC 11 Sep 2001–1800 UTC 14 Sep 2001) anomalies of relative humidity at 500 hPa: RH(500) in percent for (a) daytime periods (0000 and 1800 UTC) and (b) nighttime periods (0600 and 1200 UTC), derived using the NCEP–NCAR reanalysis.

erage DTR departures in the moderate susceptibility grid cells compared with the low susceptibility cells are not statistically different. These results further support our contention that the lack of commercial aircraft flying, especially in the areas of contrail high susceptibility, contributed to the 11–13 September DTR anomaly. In combination with the statistical relationship shown earlier between DTR departure and the fall-season contrail frequency (section 3b), this finding implies that the 11–13 September DTR anomaly was caused by a combination of regional-scale, contrail-induced suppression of DTR in the long-term climatological normals and the presence of extensive areas of contrail high susceptibility, which remained unexploited owing to the lack of commercial aircraft flights.

4. Summary and conclusions

These results support the hypothesis that the grounding of all commercial aircraft in U.S. airspace, and the consequent elimination of substantial jet contrail coverage during the 11–14 September 2001 grounding pe-

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Retrodicted CFAs for the Grounding Period

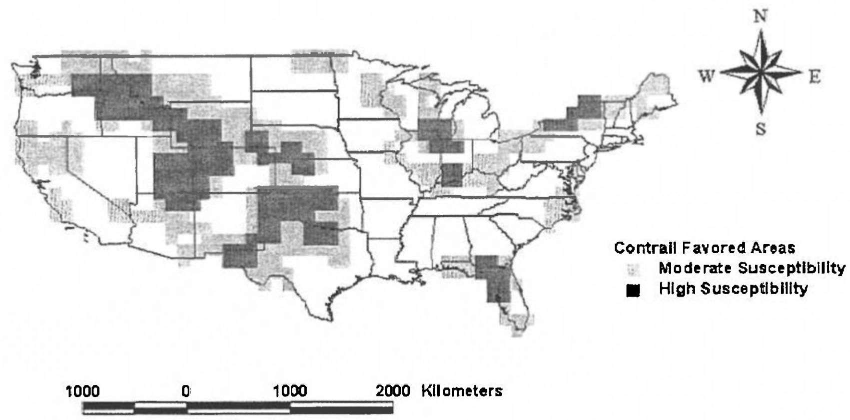

FIG. 7. Grid cell-averaged (1° × 1° resolution) map of CFAs determined for the grounding period (1800 UTC 11 Sep 2001–1800 UTC 14 Sep 2001) using the contrail-outbreak retrodiction method applied to the six-hourly NCEP–NCAR reanalyses of the upper troposphere (refer to text). The lighter (darker) shading refers to moderate (highest) susceptibility of contrail outbreaks. Those regions that were not susceptible to outbreaks are not shaded.

riod, helped produce an enhanced surface DTR in those areas that typically experience the greatest numbers of jet contrails during the fall season (e.g. the Midwest). The DTR anomaly occurred primarily due to large increases in T_{max} that were not matched by similar magnitude increases in T_{min}. In the West, synoptic weather patterns (mostly cyclonic) during the grounding period appear to have played an important role in enhancing (e.g., the Intermountain region) or negating (e.g., coastal California) the effect of contrail absence on surface temperature. For the country as a whole, the synoptic weather conditions during the grounding period suggest a better association of these with T_{min} than T_{max} thus providing a possible partial explanation for the asymmetric response of these two components of DTR.

Our analyses of the AVHRR imagery available for the grounding period indicated several occurrences of single contrails (no outbreaks) produced by military aircraft, including some in the Northeast that demonstrated extensive persistence and spreading characteristics (Minnis et al. 2002). Moreover, the analysis of other imagery showed many contrails occurring just over the border in Canada. When combined with the statistical model retrodictions, these observations suggest that if commercial airplanes had not been grounded, substantial contrail coverage would have been present over large parts of the United States, especially the Pacific Northwest, Intermountain West, upper Midwest, and Great Lakes and the Northeast.

Predicted future increases in aircraft flight frequencies, and subsequent increased occurrences of contrails in the climatologically susceptible extratropics (e.g., Gierens et al. 1999; Minnis et al. 1999), could lead to an even greater influence on DTR. However, potential changes in upper-tropospheric conditions related to global-scale climate change, which can influence both the formation likelihood and persistence time of contrails, need to be considered when projecting future impacts of contrails onto regional-scale climate.

Acknowledgments. This research was sponsored by grants from the National Science Foundation (BCS-0099011 and BCS 0099014). We are grateful to the following for their contributions to this research: Mr. Jeff Johnson (University of Wisconsin—Whitewater) for assisting with the 2000–01 contrail satellite analysis; Mr. James Q. DeGrand (The Ohio State University) for providing the 1977–79 satellite contrail frequency dataset; and the two anonymous reviewers, for their many helpful and insightful comments.

REFERENCES

Allard, J., 1997: The climatic impacts of jet airplane condensation trails (contrails) in the Northeast U.S. M.S. thesis, Dept. of Geography, The Pennsylvania State University, 152 pp. [Available from Dept. of Geography, The Pennsylvania State University, University Park, PA 16802.]

Appleman, H., 1953: The formation of exhaust condensation trails by jet aircraft. *Bull. Amer. Meteor. Soc.*, **34**, 14–20.

Bakan, S., M. Betancor, V. Gayler, and H. Grassl, 1994: Contrail frequency over Europe from NOAA-satellite images. *Ann. Geophys.*, **12**, 962–968.

Carleton, A. M., and P. J. Lamb, 1986: Jet contrails and cirrus cloud: A feasibility study employing high-resolution satellite imagery. *Bull. Amer. Meteor. Soc.*, **67**, 301–309.

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Changnon, S. A., 1981: Midwestern cloud, sunshine and temperature records since 1901: Possible evidence of jet contrail effects. *J. Appl. Meteor.*, **20**, 496–508.

Chlond, A., 1998: Large-eddy simulations of contrails. *J. Atmos. Sci.*, **55**, 796–819.

DeGrand, J. Q., A. M. Carleton, D. J. Travis, and P. Lamb, 2000: A satellite-based climatic description of jet aircraft contrails and associations with atmospheric conditions, 1977–79. *J. Appl. Meteor.*, **39**, 1434–1459.

Detwiler, A., and R. Pratt, 1984: Clear-air seeding: Opportunities and strategies. *J. Wea. Modif.*, **16**, 46–60.

Duda, D. P., P. Minnis, and L. Nguyen, 2001: Estimates of cloud radiative forcing in contrail clusters using GOES imagery. *J. Geophys. Res.*, **106**, 4927–4937.

ESRI, 1999: ArcView 3.2. Environmental Systems Research Inc.

Gierens, K., R. Sausen, and U. Schumann, 1999: A diagnostic study of the global distribution of contrails. Part II: Future air traffic scenarios. *Theor. Appl. Climatol.*, **63**, 1–9.

Gothe, M. B., and H. Grassl, 1993: Satellite remote sensing of the optical depth and mean crystal size of thin cirrus and contrails. *Theor. Appl. Climatol.*, **48**, 101–113.

Karl, T. R., and Coauthors, 1993: Asymmetric trends of daily maximum and minimum temperature. *Bull. Amer. Meteor. Soc.*, **74**, 1007–1023.

Kastner, M., R. Meyer, and P. Wendling, 1999: Influence of weather conditions on the distribution of persistent contrails. *Meteor. Appl.*, **6**, 261–271.

Kistler, R., and Coauthors, 2001: The NCEP–NCAR 50-Year Reanalysis: Monthly means CD-Rom and documentation. *Bull. Amer. Meteor. Soc.*, **82**, 247–267.

Meerkotter, R., U. Schumann, D. R. Doelling, P. Minnis, T. Nakajima, and Y. Tsushima, 1999: Radiative forcing by contrails. *Ann. Geophys.*, **17**, 1080–1094.

Mims, F. M., III, and D. J. Travis, 1997: Reduced solar irradiance caused by aircraft contrails. *Eos, Trans. Amer. Geophys. Union*, **78**, 448.

Minnis, P., J. K. Ayers, and S. P. Weaver, 1997: Surface-based observations of contrail occurrence frequency over the U.S., April 1993–April 1994. NASA Ref. Publ. 1404, May 1997, 12 pp. and tables and figs.

——, U. Schumann, D. R. Doelling, K. M. Gierens, and D. W. Fahey, 1999: Global distribution of contrail radiative forcing. *Geophys. Res. Lett.*, **26**, 1853–1856.

——, L. Nguyen, D. P. Duda, and R. Palikonda, 2002: Spreading of isolated contrails during the 2001 air traffic shutdown. Preprints, *10th Conf. on Aviation, Range, and Aerospace Meteorology*, Portland, OR, Amer. Meteor. Soc., 33–36.

Murcray, W. B., 1970: On the possibility of weather modification by aircraft contrails. *Mon. Wea. Rev.*, **98**, 745–748.

NCDC, 2003: Data documentation for Data Set 3200 (DSI-3200). National Climatic Data Center Tech. Doc. 3200, Asheville, NC, 18 pp. [Available online at ftp://ftp.ncdc.noaa.gov/pub/data/documentlibrary/tddoc/td3200.doc.]

NOAA–CIRES, cited 2002: Online Reanalysis Data. NOAA–CIRES Climate Diagnostics Center, Boulder, CO. [Available online at www.cd.noaa.gov.]

Penner, J. E., D. H. Lister, D. J. Griggs, D. J. Dokken, and M. McFarland, Eds., 1999: Aviation and the Global Atmosphere. Intergovernmental Panel on Climate Change, 12 pp.

Sassen, K., 1997: Contrail-cirrus and their potential for regional climate change. *Bull. Amer. Meteor. Soc.*, **78**, 1885–1903.

Schrader, M. L., 1997: Calculations of aircraft contrail formation critical temperatures. *J. Appl. Meteor.*, **36**, 1725–1728.

Travis, D. J., 1996: Variations in contrail morphology and relationships to atmospheric conditions. *J. Wea. Modif.*, **28**, 50–58.

——, and S. A. Changnon, 1997: Evidence of jet contrail influences on regional-scale diurnal temperature range. *J. Wea. Modif.*, **29**, 74–83.

——, ——, and S. A. Changnon, 1997: An empirical model to predict widespread occurrences of contrails. *J. Appl. Meteor.*, **36**, 1211–1220.

——, ——, and R. Lauritsen, 2002: Contrails reduce daily temperature range. *Nature*, **418**, 601.

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KING'S College LONDON

News highlights

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Proof that airports are air polluters

22 Apr 2010, PR 89/10

Scientists in the Environmental Research Group (ERG) at King's have undertaken research into the effects of the closure of UK airspace on air quality surrounding major airports after the Icelandic volcano eruption, following a number of enquiries from the public.

In response the ERG analysed the concentrations of NOX (the generic term for oxides of nitrogen combined) and NO2 (nitrogen dioxide) surrounding Gatwick and Heathrow airports during the first three days of closure, Thursday 15 to Saturday 17 April 2010. This period was chosen due to the stable weather conditions with light north easterly winds, allowing a cross-sectional analysis upwind and downwind of the airports.

This period of unprecedented closure during good weather conditions allowed the scientists to demonstrate that the airports have a clear measurable effect on nitrogen concentrations and that this effect disappeared entirely during the period of closure.

Pollution impact

Such nitrogen pollutants can increase breathing difficulties in people with existing sensibilities, cardiac conditions or in older people. Under the impact of sunlight they can transform into the even more damaging pollutant ozone. NOx and NO2 are particularly associated with jet aircraft, as they are produced by the high-temperature mix of aviation with fuel.

The analysis was undertaken by Dr Ben Barratt and Dr Gary Fuller of the Environmental Research Group, School of Biomedical and Health Sciences. *'We have always been fairly confident that there was this 'airport effect' but we have never been able to show it,'* said Dr Barratt. *'The closure gave us the opportunity to look at it, and there is a very strong indication that it is the case.*

'This exceptional closure has allowed us to demonstrate the impacts of airport emissions on their immediate neighbourhood. We did not consider the impact of decreased traffic flows on airport feeder roads in this preliminary study. Decreased traffic flows are likely to have a significant effect on concentrations of vehicle-related pollutants close to such roads, but unfortunately

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we did not have sufficient traffic data to carry out this analysis at that time,' he continued.

A full version of the report is available for download from the ERG's *London Air Quality Network* website.

Notes to editors

King's College London
King's College London is one of the top 25 universities in the world (*Times Higher Education* 2009) and the fourth oldest in England. A research-led university based in the heart of London, King's has nearly 23,000 students (of whom more than 8,600 are graduate students) from nearly 140 countries, and some 5,500 employees. King's is in the second phase of a £1 billion redevelopment programme which is transforming its estate.

King's has an outstanding reputation for providing world-class teaching and cutting-edge research. In the 2008 Research Assessment Exercise for British universities, 23 departments were ranked in the top quartile of British universities; over half of our academic staff work in departments that are in the top 10 per cent in the UK in their field and can thus be classed as world leading. The College is in the top seven UK universities for research earnings and has an overall annual income of nearly £450 million.

King's has a particularly distinguished reputation in the humanities, law, the sciences (including a wide range of health areas such as psychiatry, medicine and dentistry) and social sciences including international affairs. It has played a major role in many of the advances that have shaped modern life, such as the discovery of the structure of DNA and research that led to the development of radio, television, mobile phones and radar. It is the largest centre for the education of healthcare professionals in Europe; no university has more Medical Research Council Centres.

King's College London and Guy's and St Thomas', King's College Hospital and South London and Maudsley NHS Foundation Trusts are part of King's Health Partners. King's Health Partners Academic Health Sciences Centre (AHSC) is a pioneering global collaboration between one of the world's leading research-led universities and three of London's most successful NHS Foundation Trusts, including leading teaching hospitals and comprehensive mental health services. For more information, visit: www.kingshealthpartners.org.

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Does Air Pollution Increase Rainfall

Posted in | Energy | Climate Change | Global Warming | Pollution | Water

An international team of scientists, headed by Prof. Daniel Rosenfeld of the Institute of Earth Sciences at the Hebrew University of Jerusalem, has come up with a surprising finding to the disputed issue of whether air pollution increases or decreases rainfall. The conclusion: both can be true, depending on local environmental conditions.

The determination of this issue is one with significant consequences in an era of

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- Evergreen Solar's String Ribbon Panels to power Patriot Place
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- Puget Sound Energy Customers Connect Solar Systems to Utility Grid
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- Energy Conversion Devices and Enfinity Corporation to Develop Rooftop Solar Installations in Ontario, Canada
- Umwelt-Sonne-Energie Completes Largest Solyndra Rooftop PV System Project in Belgium
- A-Power Energy Generation Systems Delivers Wind Turbines in China
- Canadian Solar Enters into PV Modules Sales Contract with Fire Energy Group
- Northside Lofts Geothermal Project by Middleton Geothermal Services
- Energy Conversion Devices and Enfinity Corporation to

climate change and specifically in areas suffering from manmade pollution and water shortages, including Israel.

In an article appearing in the Sept 5 issue of the journal Science, the scientific team, which included researchers from Germany, has published the results of its research untangling the contradictions surrounding the conundrum. They do this by following the energy flow through the atmosphere and the ways it is influenced by aerosol (airborne) particles. This allows the development of more exact predictions of how air pollution affects weather, water resources and future climates.

Mankind releases huge amounts of particles into the air that are so tiny that they float. Before being influenced by man, air above land contained up to twice as many of these so called aerosol particles as air above oceans.

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- Research Aims to Reduce Energy Usage in the Home
- eSolar and Penglai Electric Announce Licensing Agreement to Build Solar Thermal Power Plants in China
- Northern Power Systems Selects Analog Devices' SHARC Processors for its Northwind 100 Community-Scale Wind Turbines

Nowadays, this ratio has increased to as much as a hundredfold.

Smoke from agricultural fires suppresses rainfall from a cloud over the Amazon (right). A similar size cloud (left) rains heavily on the same day some distance away in the pristine air. (Hebrew University photo)

Natural and manmade aerosols influence our climate - that much is agreed. But which way do they push it? They produce more clouds and more rain, some say. They produce fewer clouds and less rain, say others. This disputed role of aerosols has been the greatest source of uncertainties in our understanding of the climate system, including the question of global warming.

"Both camps are right", says Prof. Meinrat O. Andreae, director of the Max Planck Institute for Chemistry in Germany, a coauthor of the publication. "But you have to consider how many aerosol particles there are." The lead author, Prof. Rosenfeld of the Hebrew University, adds: "The amount of aerosols is the critical factor controlling how the energy is distributed in the atmosphere." Clouds, and therefore precipitation, come about when moist, warm air rises from ground level and water condenses or freezes on the aerosols aloft. The energy responsible for evaporating the water from the earth's surface and lifting the air is provided by the sun.

Aerosols act twofold: On the one hand, they act like a sunscreen reducing the amount of sun energy reaching the ground. Accordingly, less water evaporates and the air at ground level stays cooler and drier, with less of a tendency to rise and form clouds.

On the other hand, there would be no cloud droplets without aerosols. Some of them act as gathering points for air humidity, so called condensation nuclei. On these tiny particles with diameters of less than a thousandth of a millimeter the water condenses - similar to dew on cold ground - releasing energy in the process. This is the same energy that was earlier used to evaporate the water from the earth's surface. The

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released heat warms the air parcel so that it can rise further, taking the cloud droplets with it. But if there is a surplus of these gathering points, the droplets never reach the critical mass needed to fall to earth as rain – there just is not enough water to share between all the aerosol particles. Also, with a rising number of droplets their overall surface increases, which increases the amount of sunlight reflected back to space and thus cooling and drying the earth.

In a nutshell, then, the study results show the following: With rising pollution, the amount of precipitation at first rises, than maxes out and finally falls off sharply at very high aerosol concentrations. The practical result is that in relatively clean air, adding aerosols up to the amount that releases the maximum of available energy increases precipitation. Beyond that point, increasing the aerosol load even further lessens precipitation. Therefore, in areas with high atmospheric aerosol content, due to natural or manmade conditions, the continuation or even aggravation of those conditions can lead to lower than normal rainfall or even drought.

Prof. Rosenfeld states: "These results have great significance for countries like Israel where rainfall is scarce and can be easily affected by over-production of aerosols. Our study should act as a red light to all of those responsible for controlling the amounts of pollution we release into the atmosphere."

"With these results we can finally improve our understanding of aerosol effects on precipitation and climate," summarizes Andreae, "since the direct contradiction of the different aerosol effects has seriously hindered us from giving more accurate predictions for the future of our climate, and especially for the availability of water."

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APPENDIX 8

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Rain Men: Scientists Here Tried to Change the Weather

By Chrissie Reilly
Staff Historian

(Note: This article appeared in the 20 Feb 2009 issue of the *Monmouth Message*)

Everybody talks about the weather, but nobody does anything about it.

Except here at Fort Monmouth, where researchers changed the course of nature, and of history, in 1947.

This installation was home to Project Cirrus, a five-year foray into the science, and sometimes the art, of weather modification.

The discoveries and experiments in our very own Signal Corps Laboratories as part of Project Cirrus are still relevant, and the technology is still used worldwide.

The project was led by Nobel laureate Dr. Irving Langmuir and his protégé Dr. Vincent Schaefer, both from General Electric (GE).

Langmuir defined serendipity as "the art of profiting from unexpected occurrences." Their discovery of cloud seeding certainly qualified as one such serendipitous event.

The cloud seeding project originated with experiments in de-icing aircraft that took them to Mount Washington, New Hampshire— home of extremely harsh winter weather.

To recreate these conditions in a lab, Schaefer invented a "cold box" to test his theories. This was a GE home freezer with a black velvet lining and a viewing light.

Employees from Fort Monmouth work on the Project Cirrus equipment.

Breathing into the cold box produced a tiny cloud of supercooled water droplets, just like in the upper parts of a cloud.

Schaefer later discovered that the addition of any substance that was -40 degrees Celsius would cause millions of ice crystals to form in the cloud. They extrapolated that this would work in atmospheric clouds, too.

So the men attempted to 'seed' clouds with dry ice by flying over them and releasing the particles.

On Nov 13, 1946, Shaefer dropped 1.4 kg of dry ice pellets from an airplane into a supercooled stratus cloud near Schenectady, New York. And snow fell!

In February 1947, the US Army Signal Corps became involved in these cloud seeding missions, and it earned the name Project Cirrus.

The project was a joint effort of the Army, Navy, Air Force, and GE.

William R. Cotton and Roger A. Pielke wrote about Langmuir's and Schaefer's exploration into cloud seeding with cirrus clouds, supercooled stratus clouds, cumulus clouds, and even hurricanes in their book *Human Impacts on Weather and Climate*.

The supercooled stratus clouds were the most responsive to seeding, and patterns (including L-shapes, race tracks, and Greek gammas) could be seeded into the clouds.

Retired Fort Monmouth physicist Sam Stine worked at the Evans Signal Laboratory designing experiments. He then had the job of getting into the airplanes and actually testing them.

Project Cirrus plane in flight.

According to Stine, "We flew about 37 experimental flights in the first year and a half. Flying into thunderstorms, line squalls, the tops of tornadoes, you have it."

Because of the inherent variability in weather patterns, attempts to modify weather did not always yield perfect or consistent results; there was also the problem of reliably attributing results to specific scientific actions.

Dr. Harold Zahl recalled in his book, *Electrons Away, or Tales of a Government Scientist*, "There were conditions when rain or snow could be precipitated, but the moisture had to be there in the first place. Nature had to be a cooperating partner and, when needed most, it seemed that she was not always ready to help."

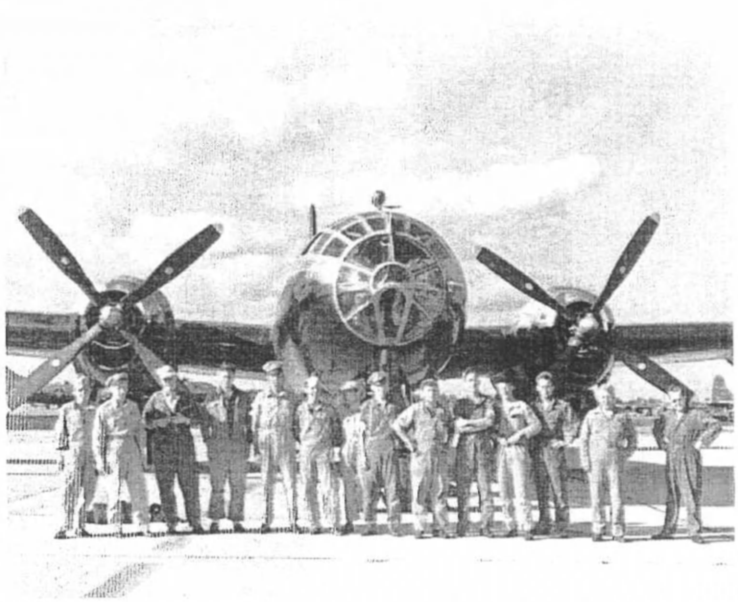
Cloud seeding did not always produce the expected results.

The first attempt at modifying a tropical cyclone or hurricane occurred in 1947. It was October and a hurricane was head eastward off the coast of Florida and into the Atlantic.

After 80 lbs of dry ice were dispersed into the hurricane, it briefly paused, and then headed for the shore. Winds of 85 mph were clocked in Savannah, GA, a resident there was killed, coastal areas flooded, and the damage totaled over $20 million.

VIII, 4

Jay Barnes and Steve Lyons reported in *Florida's Hurricane History*, that many believed that the seeding was responsible for the turn, including Langmuir. Hurricanes had however behaved like this in the past without seeding – only 40 years prior a hurricane did the same thing and headed due west into the coast.



Project Cirrus was a joint effort of the Army, Navy, Air Force, and General Electric. This photo was taken before one of the many flights in 1948.

Zahl reported that "we concluded it was 'an act of God.' If it could happen once, it could happen twice."

Either way, GE's lawyers told Langmuir not to discuss the hurricane until the statute of limitations had run out for prosecution.

The technology involved in Cirrus was put to good use also in October 1947, when clouds were seeded above a Maine forest fire to help extinguish the blaze.

Despite the often mixed results of Project Cirrus, Langmuir was a noted workaholic. *The New York Times* reported that upon his retirement from GE in 1950, he did not even take a vacation, but went straight to devoting more time to Cirrus.

Langmuir told reporters for a March 2, 1950 *New York Times* article that "within the past year, Project Cirrus has grown very greatly in importance, and now I believe that the best service that I can render to the national welfare is to increase my activities in this field."

He also expected the same rigorous work ethic from his lab personnel. On Thanksgiving 1951, he complained that his employees wanted days off for the holiday!

Cloud seeding and weather modification in general declined over the years, due to a number of reasons.

Weather modification was largely oversold to the public and legislative members; an abnormal wet period in the United States reduced demand; and changes in government and public attitudes towards other weather and climate concerns all contributed to less seeding projects over the years.

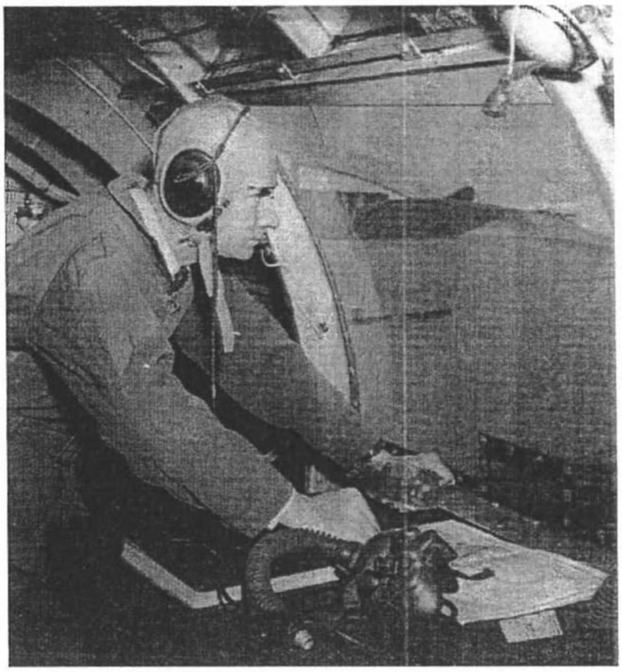
Despite this controversy, it has not stopped people continuing to try to control the weather.

VIII, 5

The 2008 Olympic Games held in Beijing were scheduled during northern China's rainy season.

In order to prevent rain from ruining the opening ceremonies in the open-air birds nest stadium, the Chinese government seeded clouds with silver iodide to make it rain elsewhere. And there was no rain in Beijing for the opening events.

The Signal Corps Laboratories at Fort Monmouth were at the forefront of scientific exploration. What rain dances had been attempting to do for centuries, Fort Monmouth accomplished.



Dr. Vincent Schaefer prepares for a Project Cirrus flight in 1948.

IX, 1

APPENDIX 9

[Top Secret hearing held on March 20, 1974; made public on May 19, 1974]

WEATHER MODIFICATION

WEDNESDAY, MARCH 20, 1974

UNITED STATES SENATE,
SUBCOMMITTEE ON OCEANS AND
INTERNATIONAL ENVIRONMENT OF THE
COMMITTEE ON FOREIGN RELATIONS,
Washington, D.C.

The subcommittee met, pursuant to notice, at 2:30 p.m., in room S-116, Capitol Building, Senator Claiborne Pell [chairman of the subcommittee] presiding.

Present: Senators Pell and Case.

Also present: Dr. Pierce S. Cordan, U.S. Arms Control and Disarmament Agency.

Senator PELL. Gentlemen, I think we might as well get started. Some of my colleagues will be coming in, but I think it is important to get on with this meeting today and lay out the record.

Why don't you introduce yourselves and then proceed as you will, after which I have a series of questions.

STATEMENT OF DENNIS J. DOOLIN, DEPUTY ASSISTANT SECRETARY OF DEFENSE (EAST ASIA AND PACIFIC AFFAIRS); ACCOMPANIED BY MAJ. GEN. RAY FURLONG, USAF, DEPUTY ASSISTANT SECRETARY OF DEFENSE (LEGISLATIVE AFFAIRS); LT. COL. ED SOYSTER, USA, ORGANIZATION OF THE JOINT CHIEFS OF STAFF; COL. ALBERT J. KAEHN, JR., O.D.D.R. & E.; AND WILLIAM CHAPIN, BUREAU OF INTERNATIONAL SCIENTIFIC AND TECHNOLOGICAL AFFAIRS, DEPARTMENT OF STATE

Mr. DOOLIN. Thank you, Mr. Chairman.

I am Dennis Doolin, Deputy Assistant Secretary of Defense for East Asia and Pacific Affairs. This is Maj. Gen. Ray Furlong, Deputy Assistant Secretary of Defense for Legislative Affairs, and Lt. Col. Ed Soyster of the Office of the Joint Chiefs of Staff, who will be your briefer today. If it meets with your approval, I propose that Colonel Soyster will give the briefing.

Colonel Soyster.

Colonel SOYSTER. The purpose of this briefing is to provide information on the only DOD classified weather modification activity—this being our rainmaking in Southeast Asia.

IX, 2

[Chart 1 follows:]

CHART 1

SEASIA RAINMAKING

[SUPPLIED BY DEPARTMENT OF DEFENSE]

A CLASSIFIED RAINMAKING PROGRAM WAS CONDUCTED IN SEASIA FROM 1967 TO 1972 WHICH EMPLOYED AIR DROPPED SILVER AND LEAD IODIDE SEEDING UNITS TO INCREASE NORMAL MONSOON RAINFALL.

PURPOSE OF OPERATIONS

Colonel SOYSTER. The purpose of this operation was to make difficult the North Vietnamese infiltration through the Laotian panhandle and Plain Des Jarres.

EFFECTS OF NORTHEAST AND SOUTHWEST MONSOON SEASONS

This area of Southeast Asia has two principal seasons—the northeast monsoon and the southwest monsoon.

During the northeast monsoon the rainfall is light or nonexistent and even unimproved roads are unaffected by the limited rains. During the southwest monsoon the rainfall is heavy and almost daily. As a result, the unimproved roads in this region become soaked and will not support vehicular traffic. From the beginning of our efforts in Southeast Asia, operational personnel would rely on the coming wet season brought by the southwest monsoon to contribute greatly to the enemy's logistic difficulties.

The close monitoring of troop and truck traffic along routes where rain had fallen verified beyond any doubt the naturally adverse effects of rainfall and accumulated soil moisture on the enemy's logistic effort. From April to mid-May, as the spring transition to the southwest monsoon occurs, it was found that even isolated thundershowers temporarily interrupted logistic operations. Most unimproved vehicular route surfaces are hard due to the relatively dry weather conditions that prevail in Laos during the northeast monsoon. When intermittent rain falls on this kind of surface, runoff is quick and virtually complete. However, as both the amount and frequency of rainfall increases—this is from the period of May through June, the ground begins to soak up more and more moisture until it becomes saturated. When this condition is created, the

ground remains "soggy" for extended periods with only moderate amounts of rain needed to maintain saturation. At this point, vehicular travel becomes extremely difficult if not impossible. Typically, by the end of June, the southwest monsoon is well established and soil moisture has reached the point where roads remain soggy. These conditions continue through September. The fall transition to the dry northeast monsoon then begins with less rainfall in the area.

OBJECTIVE OF PROGRAM

The program was to increase rainfall sufficiently in carefully selected target areas to further soften the road surfaces, cause landslides along roadways, and to wash out river crossings. These events normally and naturally occur anyway during the height of the rainy season. By seeding it was intended to extend the period of occurrence beyond the normal rainy season and to supplement the natural rainfall as required to maintain the resultant poor traffic conditions.

[Chart 2 follows:]

CHART 2

OBJECTIVE

[SUPPLIED BY DEPARTMENT OF DEFENSE]

INCREASE RAINFALL SUFFICIENTLY IN CAREFULLY SELECTED AREAS TO DENY THE ENEMY THE USE OF ROADS BY:

(1) SOFTENING ROAD SURFACES

(2) CAUSING LANDSLIDES ALONG ROADWAYS

(3) WASHING OUT RIVER CROSSINGS

(4) MAINTAIN SATURATED SOIL CONDITIONS BEYOND THE NORMAL TIME SPAN

TECHNIQUE USED

Colonel SOYSTER. The technique that was used takes advantage of an important natural process that causes rainfall in cumulus clouds in the tropics. In this natural process when a strong temperature inversion exists, clouds frequently grow to the level of the inversion and only occasional turrets succeed in rising to greater heights.

Senator PELL. What is an inversion?

Colonel SOYSTER. Normally temperature goes from a warmer to a colder condition as you rise in altitude. In an inversion it is reversed, that is the cold air is on the bottom.

As the turret passes the inversion, it rises first through slightly warmer air and then into a colder, much drier region. As the turret reaches its apex and begins to cool larger droplets of moisture begin to form and the previously white clouds begin to darken and descend into

IX-3

the mass below the collapsing portion of the cloud. The falling drops grow by condensation for a short while because they are colder and then by collision with the underlying, smaller, more slowly falling droplets. The techniques employed, which I will describe next, accentuate this natural process by causing cloud growth with subsequent collapse. In many respects, effective seeding of a marginal convective cloud is akin to bringing a banked furnace to life. With this in mind, let me now describe the technique used.

In general, cloudseeding involves locating updrafts in clouds and releasing small amounts of seeding material into the updrafts. The seeding agent causes supercooled drops to freeze, releasing energy (heat) and a more rapid condensation of water vapor on the frozen drops than is possible on the liquid droplets, with, of course, the accompanying faster release of energy. Clouds appear to operate at near equilibrium conditions and even a small change in energy release causes a change in updraft velocity, heating makes the air rise faster and the updraft area and velocity is increased, sucking in more moist air from below and causing condensation throughout the ascending column.

This chart illustrates the air flow. As shown at (A), rapidly growing towers frequently develop a pileus, or small cloud directly above the updraft. This is a good indication of updraft position. Air comes in the bottom of the cloud, flows up through it, past the visible top and down around the sides, much like a bubble fountain. A downdraft surrounds the sides of the clouds, at least at seeding altitudes.

At (B)—Following seeding, the central portion rises rapidly and the base widens. Usually, the portion above the freezing level doubles in volume in 3 to 5 minutes. Updrafts inside are intensified, the total downdraft external to the cloud increases.

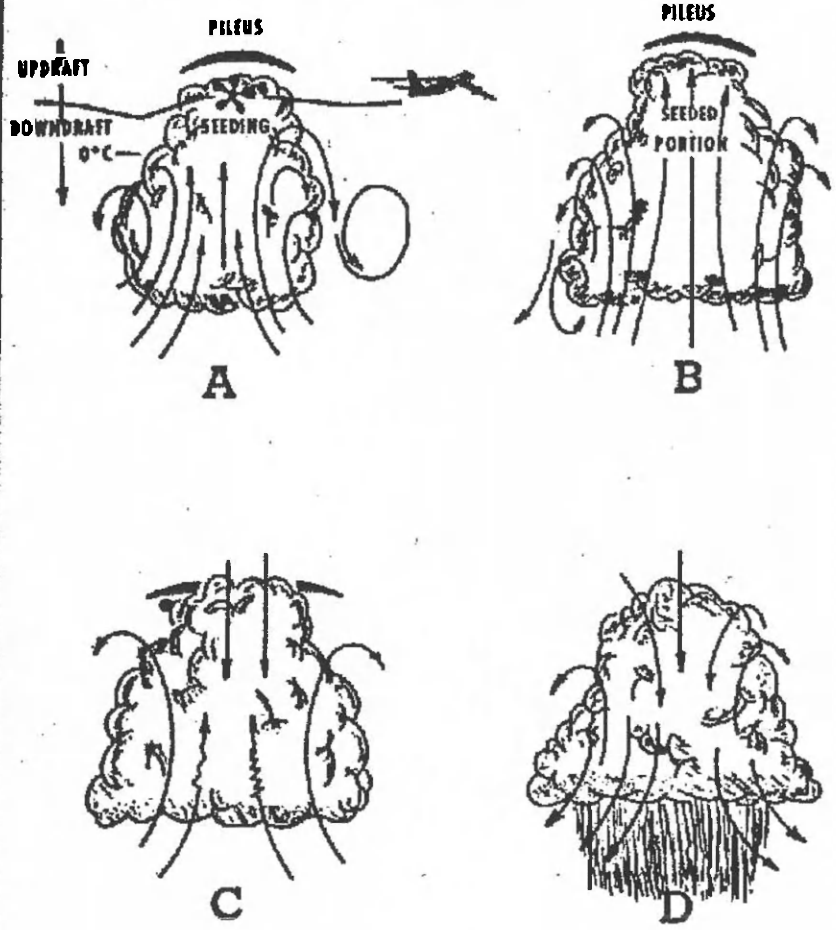
Turning to (C)—At apex, the cloud ceases to grow vertically, the top begins to evaporate and begins a gentle descent into the mass beneath, where the droplets run into still ascending air carrying cloud water upward.

And finally at (D)—A rain shower develops as the cloud collapses. The sequence closely resembles a typical rain shower process in the tropics, except that the presence of ice, which the seeding has caused to form in the process is not natural in tropical rain showers.

[Chart 3 follows:]

CHART 3.—Cloudseeding Technique

[Supplied by Department of Defense]



SEEDING UNITS AND TECHNIQUE

Colonel SOYSTER. The seeding units used to seed were developed at the Naval Weapons Center, China Lake, Calif. and are not classified. The seeding units and technique are identical to those used in publicized rainmaking projects—for example, Philippines, Okinawa, Texas—and the Stormfury research project.

The seeding units consist of a 40 mm aluminum photoflash-type cartridge case with primer and a candle assembly. The candle assembly incudes a plastic container 3 inches long with the seeding material and necessary delayed firing mechanism to ignite the free falling container. The silver iodide or lead iodide is produced as the chemical mixture burns.

The burning time is about 36 seconds for the most commonly used type. The unit drops about 3,000 feet during its functional burn. The units are dropped inside the cloud in the active updrafts at intervals of approximately one-half mile.

The release is normally controlled by the pilot flying the aircraft who can best determine the location of the updrafts. Two types of aircraft were used—the WC–130 weather reconnaissance aircraft and the RF–4C reconnaissance aircraft. The WC–130 carried pods containing 104 units each on both sides of the aircraft fuselage just forward of the paratroop jump door. The RF–4C carried a total of 104 units in the photo cartridge compartments. Typically, these aircraft could influence an average of 4–5 clouds or groups of clouds per day during the southwest monsoon.

The technique requires that specific individual clouds be seeded. Their growth is related to atmospheric conditions and the amount of seeding so that when the seeding ends, the thunderstorm created acts like any other storm and is short-lived because the seeding materials either rain out, disperse, or decompose.

REQUIREMENTS FOR AND EFFECTS OF FAVORABLE SEEDING

Over-seeding or improperly placed seeding tends to disperse the clouds. There is no chance of prolonged effects. Under nearly perfect conditions, effects last possibly 6 hours maximum. Normally, the effect is about one-half hour. Further, favorable seeding requires low velocity and unidirectional winds to prevent dispersal. The effects are therefore limited in area, perhaps 20-mile diameter under ideal conditions and continuous seeding where groups of clouds could be knitted together to form one large storm center. With this background in technique in mind, let me now turn specifically to our program.

1966 PILOT PROGRAM

In 1966, the Office of Defense Research and Engineering proposed a concept of using these known weather modification techniques in selected areas of Southeast Asia as a means of inhibiting enemy logistical operations.

During October 1966, a scientifically controlled test of the concept and seeding techniques was conducted in the Laos Panhandle. The test was conducted under the technical supervision and control of personnel from the Naval Ordnance Test Station (now Naval Weapons Center), China Lake, Calif., using in-theater resources. Fifty-six seedings were conducted, and over 85 percent of the clouds tested reacted favorably. On November 9, 1966, the Commander in Chief, Pacific [CINCPAC] reported the test completed and concluded that cloud-seeding to induce additional rain over infiltration routes in Laos could be used as a valuable tactical weapon.

Intelligence analysis of the area indicated that there would be no significant danger to life, health, or sanitation in the target areas. The sparsely populated areas over which seeding was to occur had a population very experienced in coping with the seasonal heavy rainfall conditions. Houses in the area are built on stilts, and about everyone owns a small boat. The desired effects of rainfall on lines of communication are naturally produced during the height of the monsoon season just by natural rainfall. The objective was to extend these effects over a longer period. It was neither necessary nor desirable to increase the total rainfall above the levels experienced during a normal heavy monsoon season. In fact, the normal variations in total annual rainfall were greater than the variations we could induce.

The operation was closely monitored and controlled. When reconnaissance indicated that objectives were attained in one area, the limited resources were shifted to other areas. Seeding was not conducted during periods of tropical storms when large amounts of rainfall were falling naturally and accomplishing the military objectives. It is the consensus of the scientific community that the techniques employed could not be used to create large uncontrolled storm systems accidentally or purposely.

Conversely, seeding to the extent conducted in Southeast Asia did not cause drought in neighboring areas. There is simply too much moisture in the air in that part of the world, and operations affected only a small percent of it—probably less than 5 percent. The desired effect was simply to control where that small percentage fell to the ground.

OPERATIONAL PHASE

With the success of the pilot program and the considerations just presented, the operational phase began on March 20, 1967, and was conducted each subsequent year during the rainy southwest monsoon (March–November) until July 5, 1972.

Senator PELL. Would you repeat that sentence?

Colonel SOYSTER. Yes, sir. After the successful pilot program and the considerations I just presented, the operational phase began on March 20, 1967, and was conducted each subsequent year during the rainy southwest monsoon; that is the period March through November until July 5, 1972, when we flew the last mission.

The program was authorized three WC–130 and two RF–4C aircraft with associated crews and maintenance personnel. These aircraft provided two WC–130 and one RF–4C sorties per day, when required. However, these aircraft, which operated out of Thailand, were not dedicated exclusively to the cloudseeding missions. The WC–130's also conducted tropical typhoon reconnaissance and tactical weather reconnaissance support missions. RF–4C's performed regular photo reconnaissance missions. The annual cost of the total program was approximately $3.6 million covering operation and maintenance, temporary duty pay, and seeding materials.

AUTHORIZED AREAS OF OPERATIONS

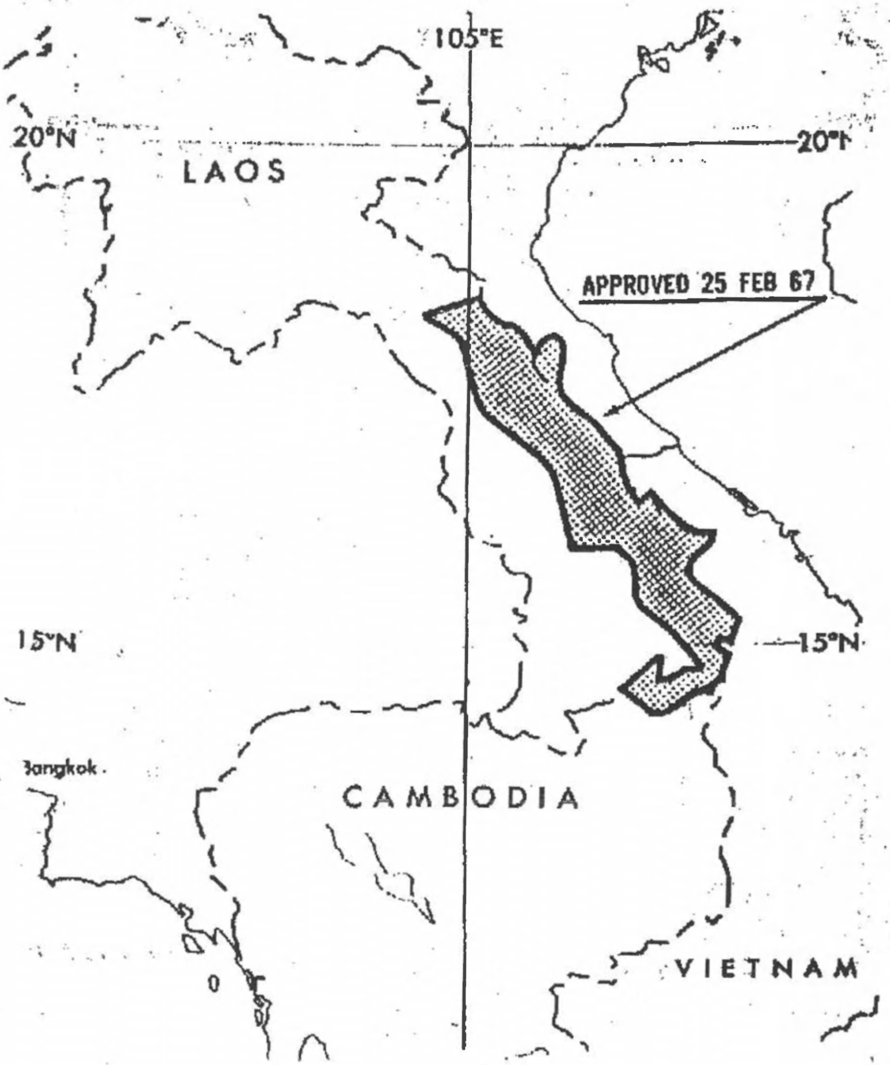
In answer to the question "Where was it done?" I will now show the authorized areas as they developed chronologically with sortie rate and amount of seeding expended.

This map illustrates the area initially authorized for operations in Laos and a very small portion of North Vietnam.

[Chart 4 follows:]

CHART 4.—Initially authorized area of operations.

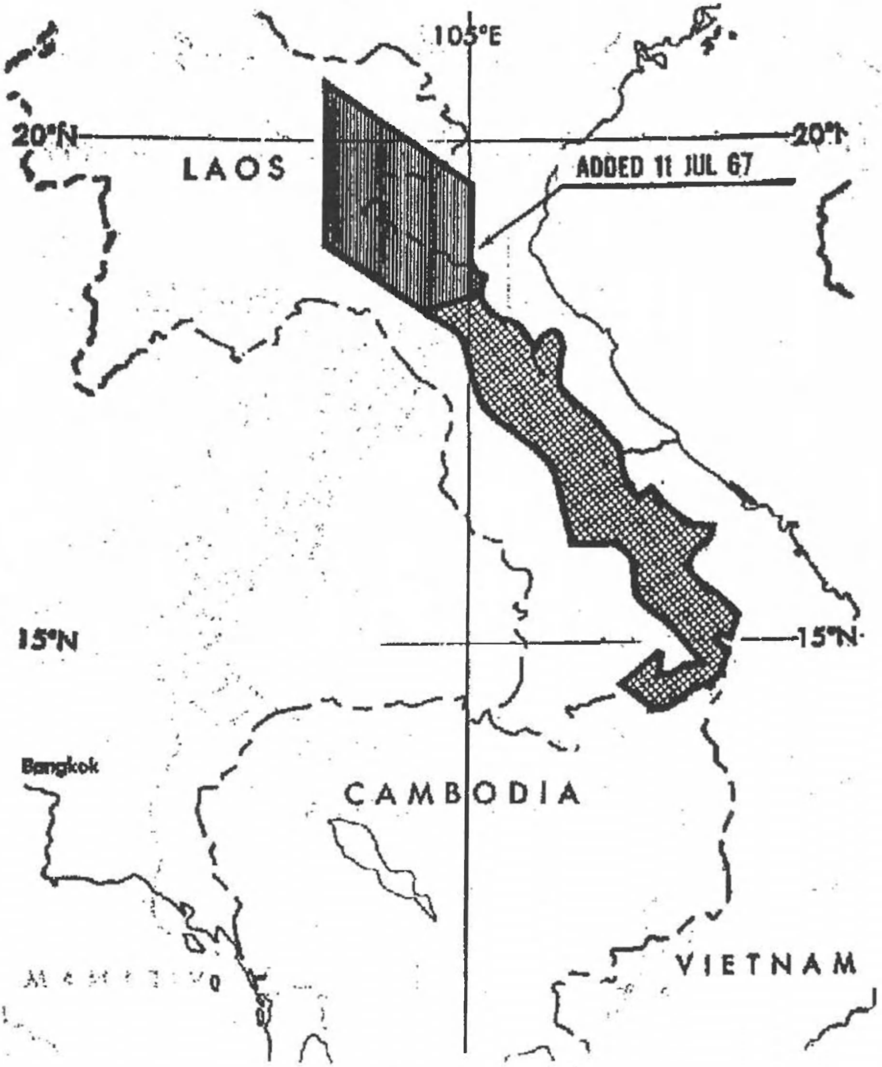
[Supplied by Department of Defense]



Colonel SOYSTER. An area encompassing additional portions of Laos and North Vietnam was added on July 11, 1967.
[Chart 5 follows:]

CHART 5.—Additional area of operations authorized on July 11, 1967.

[Supplied by Department of Defense]



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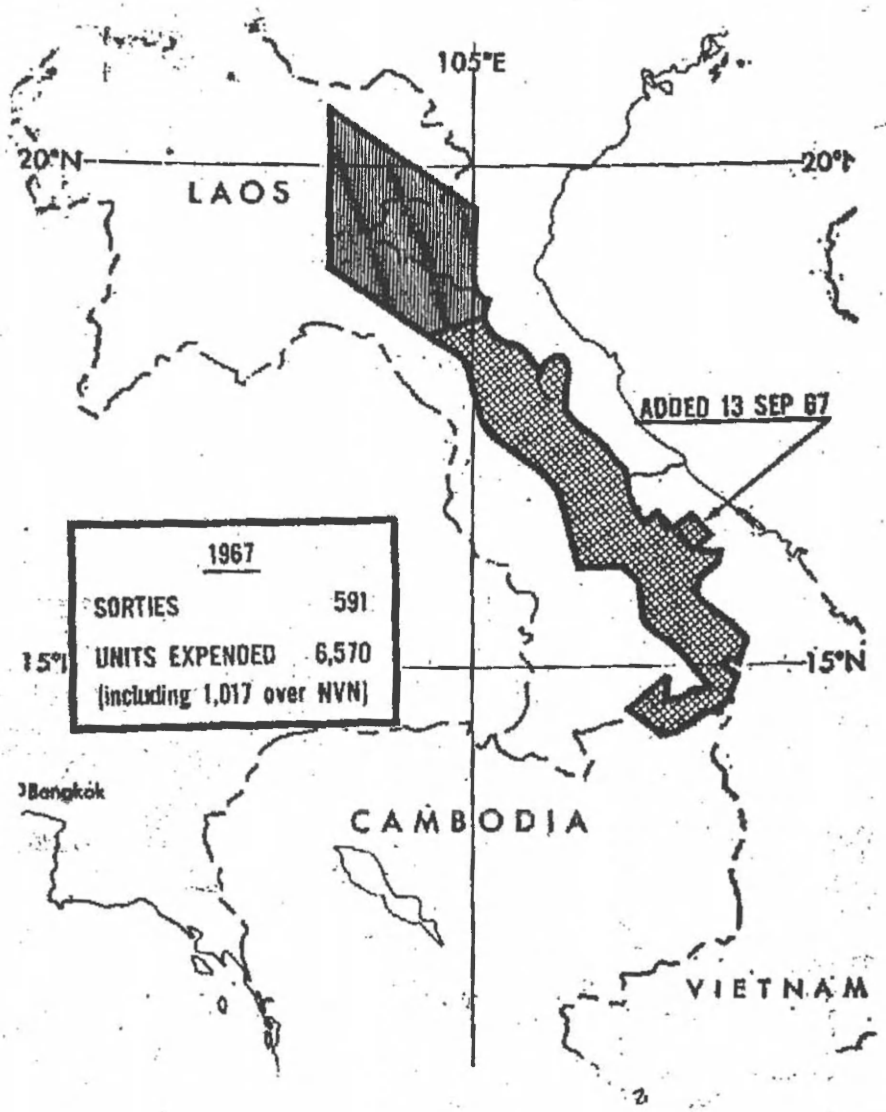
Colonel SOYSTER. Finally, a small area over the A Shau Valley in South Vietnam was added on September 13, 1967. The chart also shows the total sorties flown and the units expended for 1967.

[Chart 6 follows:]

CHART 6.—Area of operations added on September 13, 1967, and sorties flown and units expended for 1967.

[Supplied by Department of Defense]



Senator PELL. The units expended.

Colonel SOYSTER. Yes, sir; the number of 40 mm photoflash-type cartridges, as I have described, which were expended. We expended

1,017 over North Vietnam. The total sorties include both WC–130 and RF–4.

Senator PELL. Looking at the picture the concentration was more on North Vietnam, six of the units in those two small spaces. I see it would add up about the same.

Colonel SOYSTER. Yes, sir. Of course, these were expended over specific clouds over certain trails which I will talk about a little later.

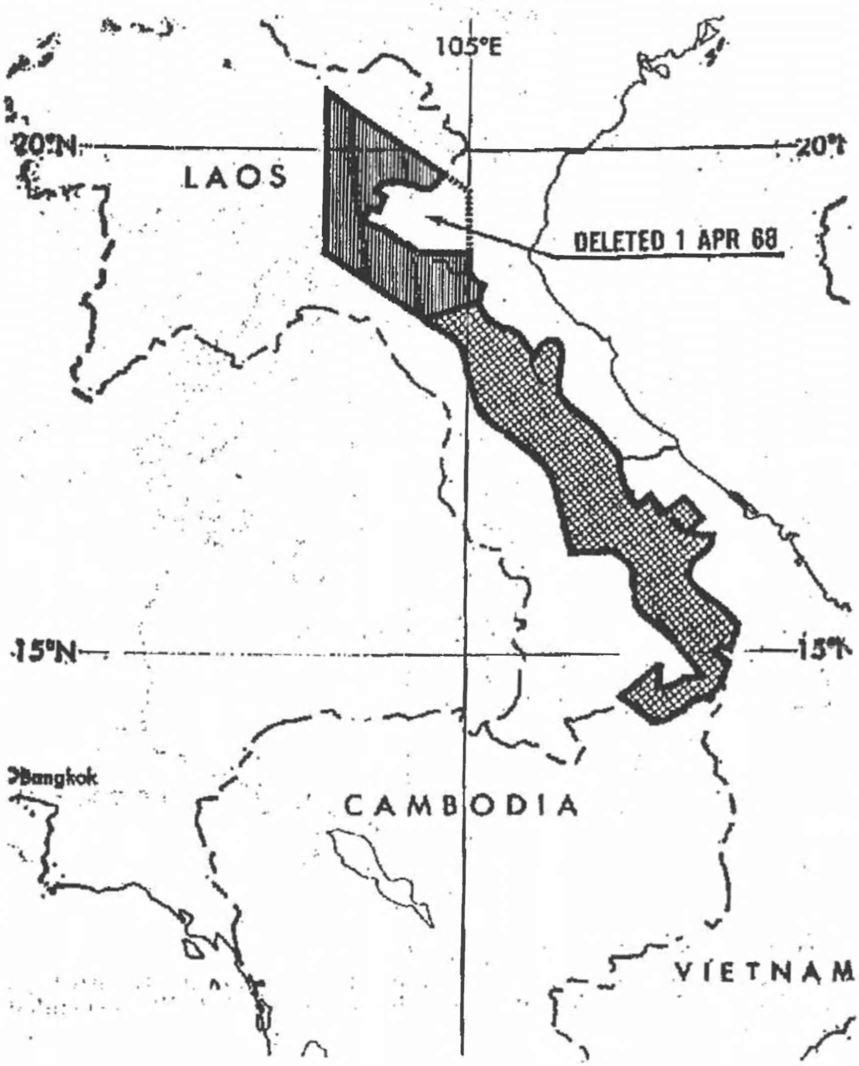
The next slide reflects the areas just briefed as they began in 1968.

On April 1, 1968, operations over North Vietnam were restricted to the area south of 19°N coincident with restrictions on bombing above that line.

[Chart 7 follows:]

CHART 7.—Restrictions of operations over North Vietnam on April 1, 1968.

[Supplied by Department of Defense]

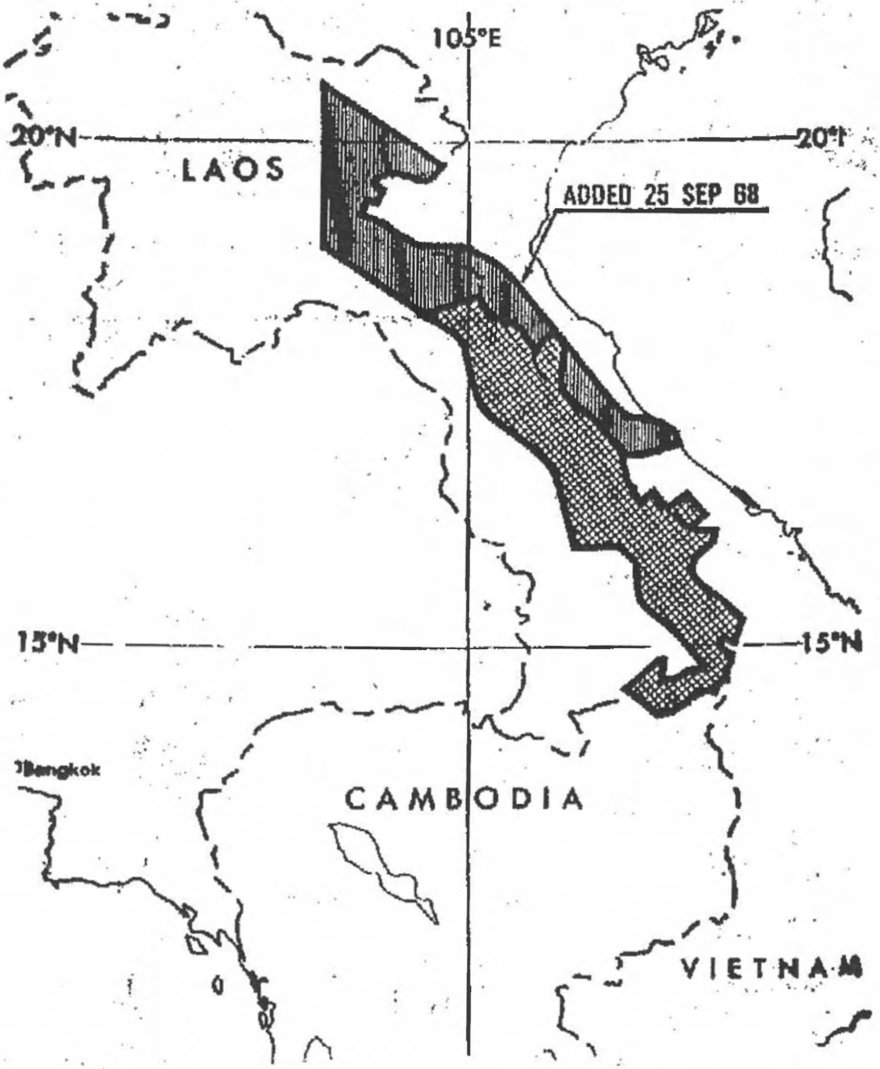


Colonel SOYSTER. An area of North Vietnam was added on September 25, 1968.

[Chart 8 follows:]

CHART 8.—Area of North Vietnam added on September 25, 1968.

[Supplied by Department of Defense]



Colonel SOYSTER. However, on November 1, 1968 all seeding operations within the boundaries of NVM were terminated and never reinstituted. This chart also shows the sorties and units expended for 1968.

Operations in 1969——

Senator PELL. Excuse me. When was it that you terminated?

Colonel SOYSTER. November 1, 1968, sir.

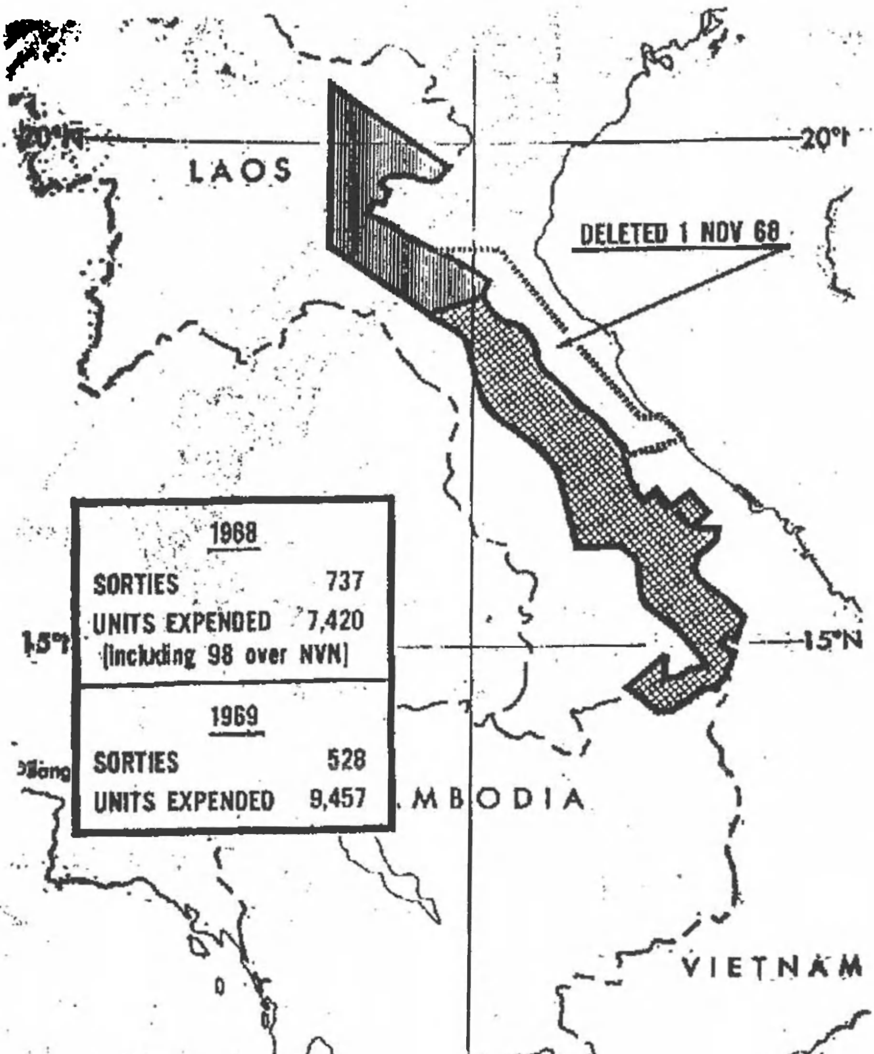
Senator PELL. Thank you.

Colonel SOYSTER. Operations in 1969 were conducted in the areas outside North Vietnam approved for 1968 and again the number of sorties and units expended are shown.

[Chart 9 follows:]

CHART 9.—November 1, 1968, termination within North Vietnamese boundaries and sorties and units expended for 1968 and 1969.

[Supplied by Department of Defense]



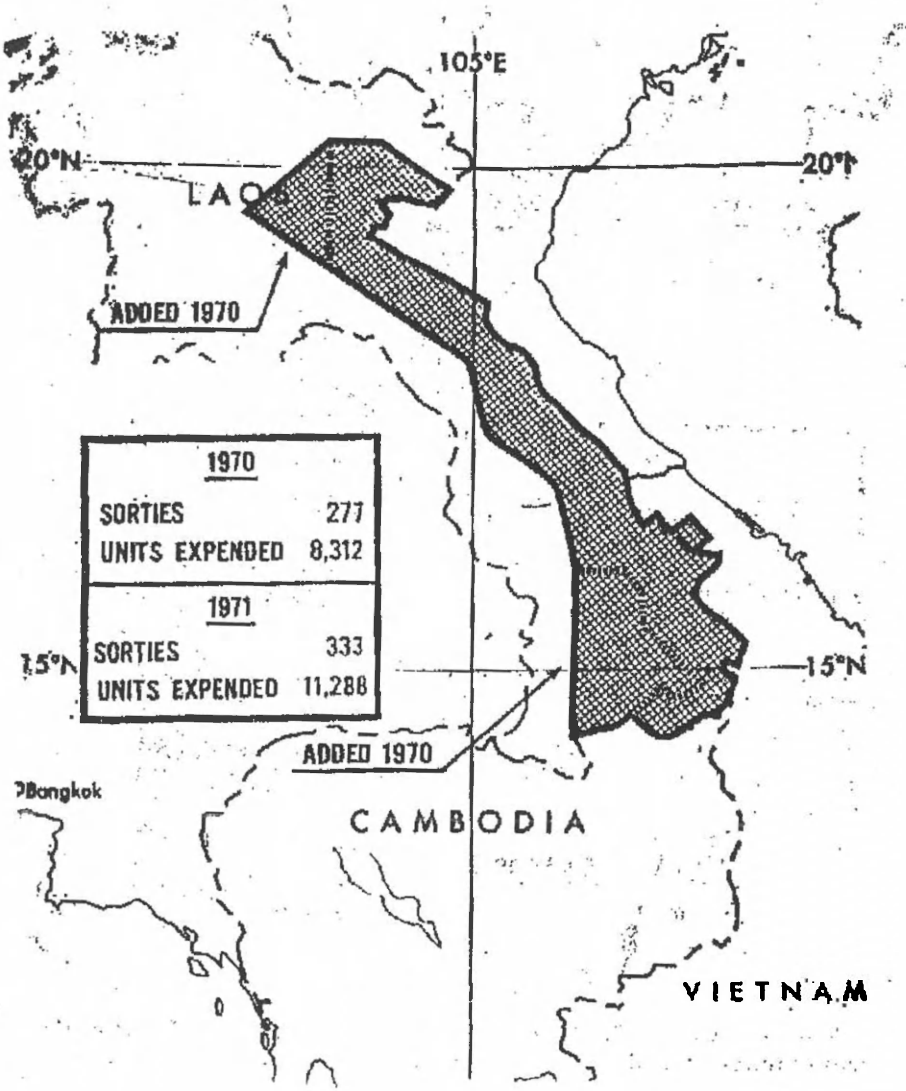
Colonel SOYSTER. During 1970, operational areas in Laos were modified as shown in the north and in the south. These are the units expended.

The 1971 area remained the same. These are the 1971 units and sorties expended in 1971.

[Chart 10 follows:]

CHART 10.—1970 modification of operational areas in Laos and sorties and units expended, 1970 and 1971.

[Supplied by Department of Defense]

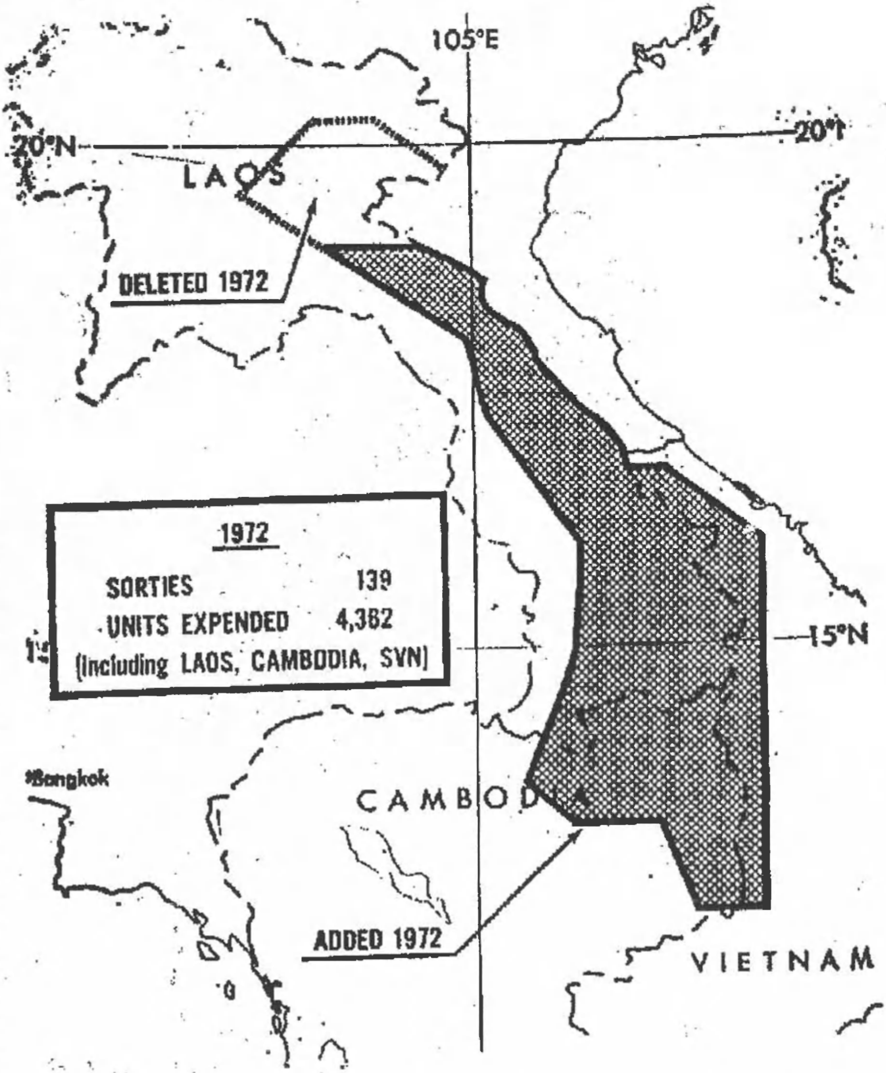


Colonel SOYSTER. The area was modified in 1972 to include portions of Northeast Cambodia and South Vietnam and to limit activity to south of 19° north in Laos.

[Chart 11 follows:]

CHART 11.—1972 modification of area.

[Supplied by Department of Defense]



Colonel SOYSTER. The next chart provides a wrap-up of sorties and seeding units expended for the program.

IX, 9

[Chart 12 follows:]

CHART 12.—Sorties and seeding units expended for program.

[Supplied by Department of Defense]

YEAR	SORTIES FLOWN	UNITS EXPENDED
1967	591	6,570 (INCLUDING 1,017 OVER NVN)
1968	734	7,420 (INCLUDING 98 OVER NVN)
1969	528	9,457
1970	277	8,312
1971	333	11,288
1972	139	4,362 (LAOS, CAMBODIA, SVN)
TOTALS	2602	47,409

AVAILABILITY OF CHARTS

Senator PELL. Incidentally, just for the record, could these charts be made available for the top secret record?

Mr. DOOLIN. Certainly, sir.

SELECTION OF TARGETS

Colonel SOYSTER. The selection of targets or areas of seeding was based on the strategic importance of lines of communication and their susceptibility to interdiction by increased rainfall. Target priorities were assigned and updated on the basis of continuous analysis of all available intelligence information at 7th Air Force, Tan Son Nhut, South Vietnam. Priorities were stated in terms of drainage basins rather than points because of the low probability that a cloud favorable for seeding would form over a specific point. It was usually possible to seed every suitable cloud within a drainage basin, but priority was given to seeding clouds directly over roads, intersections, and river crossings within each basin.

RESULTS OF PROJECT

The results of the project cannot be precisely quantified. This is due to the lack of sufficient ground stations to report. However, the Defense Intelligence Agency, using empirical and theoretical techniques based on units expended and the physical properties of the air mass seeded, estimated that rainfall was increased in limited areas up to 30 percent above that predicted for the existing conditions. Sensor recordings and other information following seeding indicated enemy difficulties from heavy rainfall.

Subjectively, it is believed that this rainfall was heavier than that which would have fallen normally and that it did contribute to slowing the flow of supplies into South Vietnam along the Ho Chi Minh trail.

EFFECTIVENESS OF PROJECT

The next series of charts will be presented to provide some feel for the effectiveness of the project. The month of June 1971 will be addressed. June is a month in which the southwest monsoon is well established. It is also a month where it is not unusual for that southwest flow to be temporarily disrupted by the intrusion of a tropical storm moving into the Southeast Asian Peninsula from the east. This was the case for June 1971 when the southwest monsoon was disrupted by typhoon Anna as the month began and later in the month by typhoon Frieda and tropical storm Golda.

These storms, although bringing heavy natural rainfall, also caused poor seeding conditions by covering the area with a thick layer of high clouds which limit the effects of surface heating required for good convective activity. I provide this to point out that there was not a consistent presence of favorable conditions for seeding even in the middle of the rainy season. As a result, daily seeding unit expenditures vary greatly as shown on this chart.

I would like to point out while this chart is up that at the beginning of April remote sensors were detecting over 9,000 enemy logistic movers per week in eastern Laos. By the end of June this number was less than 900.

Two of the most significant weekly drops in detected traffic movement occurred during June. One of these weeks was June 2 to 9 during which a typhoon was increasing rainfall and the second was during June 16 to 23 when we were most active with seeding activities during the month.

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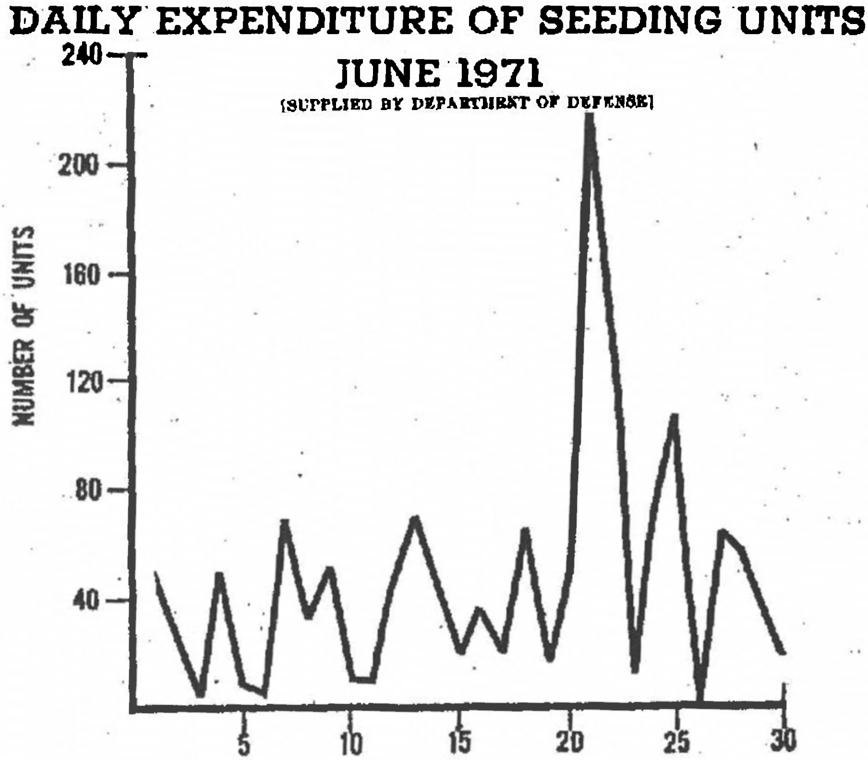
[Chart 13 follows:]



This chart is an evaluation of the units expended by week. The left-hand column gives the total seeding units expended. The next column shows the number that were successful in the crews' judgment, which is to say that they had a positive effect on the cloud and either increased rainfall rate or caused cloud growth and development.

Under "Number of Groups" and "Number of Isolated Clouds" there is an evaluation where "S" means successful as I have just described, "NE" is no effect—and "F" indicates failure or a decrease in rainfall or cloud deterioration. The final columns show the number of lines of communications which were "influenced"—A route segment is said to have been influenced by project augmented rainfall if it is located directly under seeded clouds or within a reasonable distance so that runoff from the rainfall would cross it.

"Interdicted" are those instances where visual or photographic reconnaissance confirms significant water damage to a route segment previously listed as "influenced."

[Chart 14 follows:]

CHART 14.—Evaluation of units expended by week, June 1971.

[Supplied by Department of Defense]

DATES	# of UNITS		# of GROUPS			# of ISOD CLDS			# of LOC'S	
	TOTAL	SUCC	S	NE	F	S	NE	F	INF	IN'TD
1-8 JUNE	241	195	25	6	2	3	3	4	55	13
9-15 JUNE	240	223	23	0	1	24	10	0	80	5
16-22 JUNE	542	497	40	6	1	8	13	0	101	25
23-30 JUNE	368	360	27	3	0	16	0	0	93	3
1-30 JUNE	1391	1275	115	15	4	51	26	4	329	46

Colonel SOYSTER. The next slide measures effectiveness by the use of isolines. Chart 15 shows the total rainfall in inches which fell in the area for June 1971. This is a measured amount of rainfall from various points connected by isolines.

The lines in chart 16 are an estimate of the maximum rainfall that was induced in the area which the lines connect. The black numbers in the center of these lines on both charts show the maximum rainfall estimated for any one point.

[Charts 15 and 16 follow:]

CHART 15.—Total Rainfall in Area, June 1971.

[Supplied by Department of Defense]

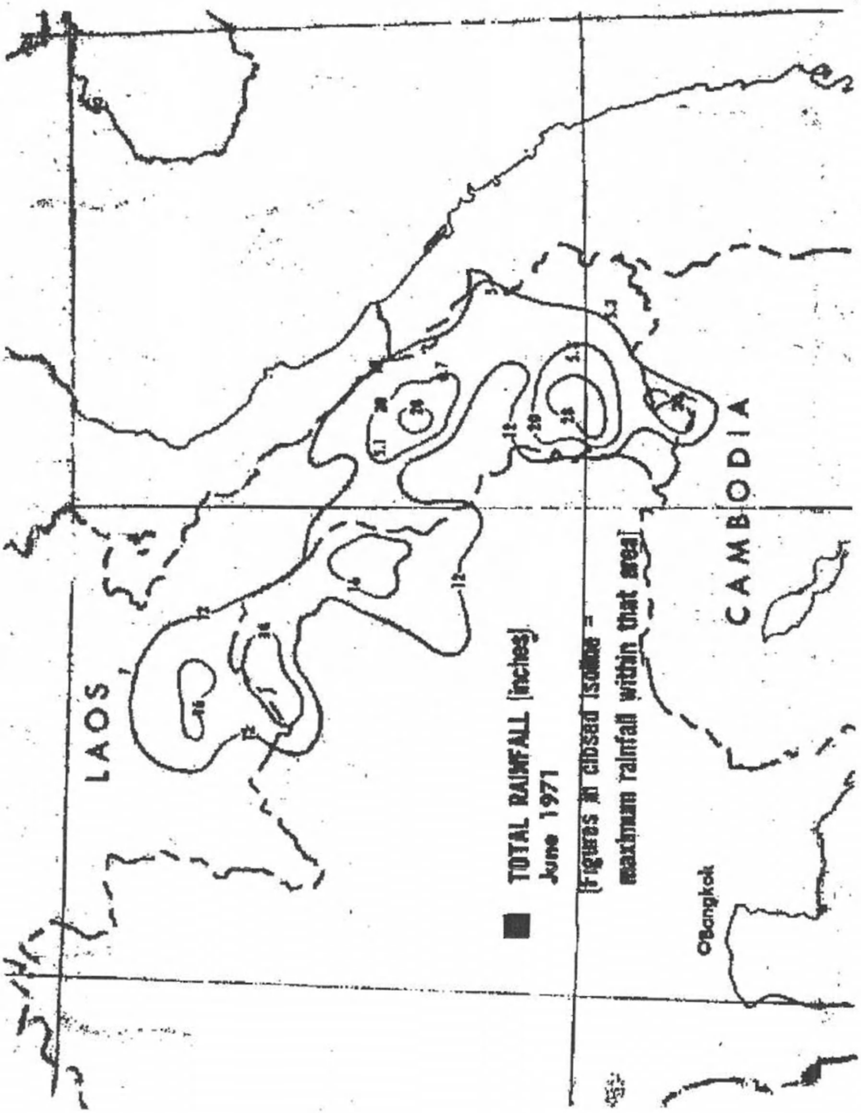
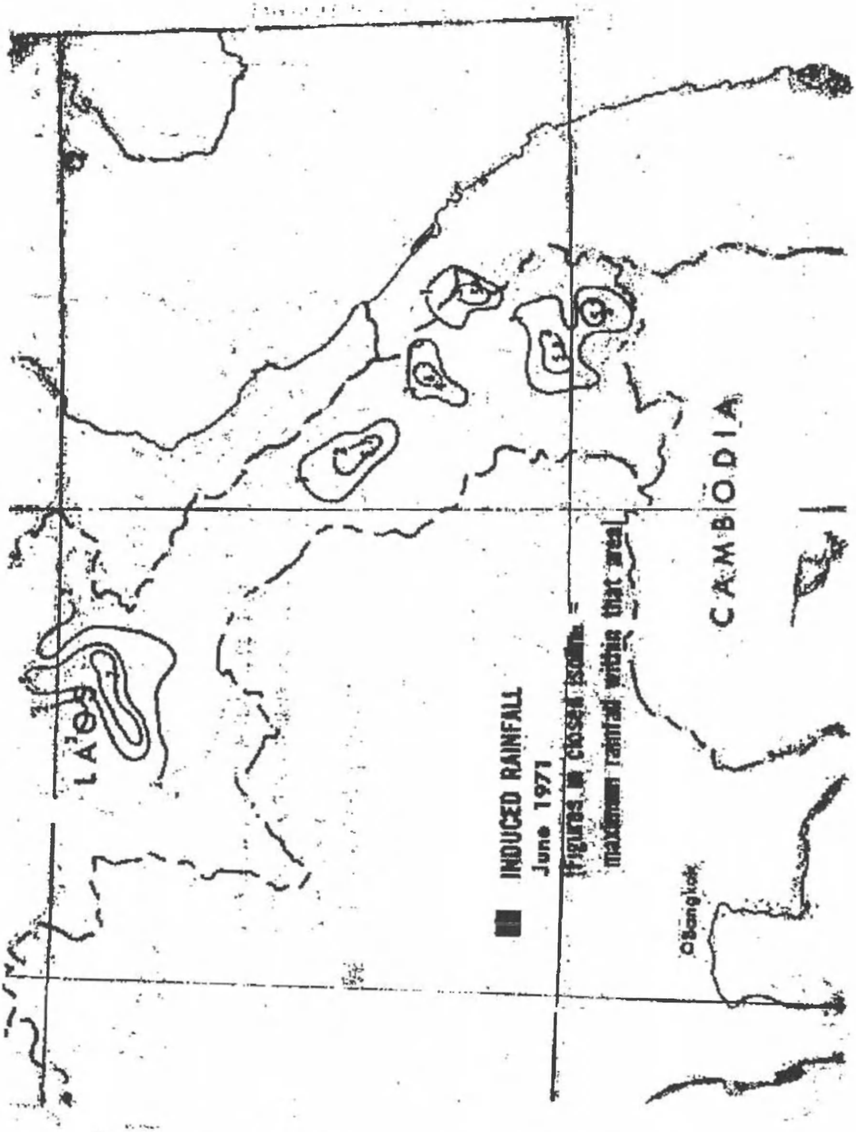


CHART 16.—Induced Rainfall In Area, June 1971.

[Supplied by Department of Defense]



PROPOSAL, TEST AND OPERATIONAL PHASE

Colonel SOYSTER. As previously mentioned, the concept of the operation was proposed in 1966 by the Office of Defense Research and Engineering.

After approval by civilian authority, the test was conducted in October 1966 and the operational phase began March 20, 1967.

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REPORTING PROCEDURES

Because the program was considered sensitive, reporting procedures were instituted to limit knowledge of the program. The WC–130 missions were flown, recorded, and reported through normal channels as weather reconnaissance flights.

The crews performed weather reconnaissance and made normal factual weather reports through regular unclassified worldwide weather channels. The RF–4C's were flown as normal reconnaissance missions. In addition to these reports, special reports to provide information to higher headquarters and to allow evaluation of the project were transmitted through special communications channels. Daily reports were submitted to the command project officer. Weekly reports were submitted through channels to the Joint Chiefs of Staff. Semiannual reports were also submitted.

Periodic reports were prepared by the Joint Staff and submitted through the chairman, Joint Chiefs of Staff to the Secretary of Defense. In order to conduct the operation approximately 14,00 personnel had to be given access to project information over a 6-year period.

These people were briefed into the project and then debriefed when they no longer required a clearance.

RESULTS OF PROGRAM

While this program had an effect on the primitive road conditions in these areas the results were certainly limited and unverifiable. It was conducted because of its apparent contribution to the interdiction mission and the relatively low program costs.

An operation such as this is almost unique to this area of the world. Rainfall can be significantly induced only where and when there are natural occurrences of heavy rains. Furthermore, induced rain can have a significant interdiction effect only where the lines of communication are relatively primitive.

Both of these conditions existed in the operating areas in Southeast Asia and, as noted, even here program effectiveness cannot be conclusively established.

This concludes the formal part of my presentation.

Senator PELL. Thank you very much, Colonel, for your good and full and frank briefing.

Is there anything further you wish to add?

Mr. DOOLIN. No; Mr. Chairman. We just wish to respond to any questions you may have, and I can leave a copy in advance of the transcript.

Senator PELL. Thank you so much.

CLASSIFICATION OF PROGRAM

As you know, in connection with the Vietnam war, all the other combat sorties and ordnance tonnages have been declassified. Why are these statistics still top secret? Why is this program still considered top secret or is it still considered top secret?

Mr. DOOLIN. We are looking at this right now, Mr. Chairman.

Senator PELL. My own reaction is one of a little bit of puzzlement. What was the reasoning behind it being so highly classified.

Mr. DOOLIN. May I ask General Furlong?

Senator PELL. What was the logic behind it?

General FURLONG. It was, of course, at that time a combat operation. I would speculate that there was concern politically as well. We did not at the time when this began discuss normal combat interdiction operations in Laos. The Government of Laos was aware of our interdiction efforts and acquiesced in it. This operation fell into a similar category.

Senator PELL. But the classification was considerably higher. I know in my own experience here that this particular program was the only program about which the DOD did not feel able to respond to questions in either public or private session.

From what you say, I am reminded of the old maxim. An "elephant labored and a mouse came forth." What was the reason for this great secrecy?

General FURLONG. Your observation—the elephant laboring and bringing forth a mouse—I think reflects in large measure our current perception of the classification.

Senator PELL. I thank you.

Mr. DOOLIN. Certainly, Mr. Chairman, I must say that it reflects my perception of the results of the program.

Senator PELL. Yes.

Mr. DOOLIN. We are actively pursuing this in terms of declassification of the information.

DECLASSIFICATION OF SECRETARY LAIRD'S LETTER

Senator PELL. In connection with declassification, you should include Secretary Laird's letter. I don't believe this end of the avenue is responsible, but copies or knowledge of copies of it seems to be available to the press. And is there any reason why you should not go ahead right quickly with the declassification of his letter?

General FURLONG. We would do that in connection with the whole. That is, you would not declassify the letter and not go ahead and declassify more.

As Mr. Doolin points out, that is being considered.

[The information referred to follows:]

THE WHITE HOUSE,
Washington, January 28, 1974.

Hon. J. W. FULBRIGHT,
Chairman, Senate Foreign Relations Committee,
U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: I have just received new information dealing with a DOD weather modification program. Since I discussed this program with you in my April 18, 1972, appearance before your committee I want to share this information with you.

During my appearance I responded to your question concerning weather modification with the statement "we have never engaged in that type of activity over North Vietnam." That statement represented, first, my knowledge that I had never approved operations over North Vietnam and secondly, my understanding of activities authorized by preceding Secretaries of Defense. I have just been informed that such activities were conducted over North Vietnam in 1967 and again in 1968. I want to take this opportunity to both express my regret that this

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information was not available to me at the time of my appearance before your Committee and to provide you with this information.

Please accept my personal appreciation for your friendship and assistance throughout my years in the Congress and the Executive Branch.

Sincerely,

MELVIN R. LAIRD,
Counselor to the President for Domestic Affairs.

JANUARY 29, 1974.

Hon. MELVIN R. LAIRD,
Counsellor to the President for Domestic Affairs,
The White House, Washington, D.C.

DEAR MR. LAIRD: Thank you for your letter of January 28 clarifying your testimony of April 18, 1972 concerning the Defense Department's weather modification activities.

I brought your letter to the attention of the Foreign Relations Committee at its meeting this morning, and the Committee instructed me to ask you if, in view of the fact, that your 1972 testimony was in public, you have any objection to making your letter public.

Sincerely yours,

J. W. FULBRIGHT,
Chairman.

FEBRUARY 11, 1974.

Hon. J. W. FULBRIGHT,
Chairman, Committee of Foreign Relations,
U.S. Senate,
Washington, D.C.

DEAR MR. CHAIRMAN: I appreciate your prompt response to my letter of January 28 concerning my testimony of April 18, 1972. Through my earlier letter I sought only to assure that you were provided with accurate information as rapidly as I received it.

It was thoughtful of you to afford me the opportunity to clarify the public record. However, to the best of my knowledge, the Department of Defense retains a security classification on this material which accounts for the classification of my letter to you.

I must, therefore, ask that my letter to you retain its classification as it would be inappropriate for me to act unilaterally without Department of Defense declassification approval.

With best wishes and kindest personal regards, I am

Sincerely,

MELVIN R. LAIRD.

FEBRUARY 14, 1974.

Hon. JAMES R. SCHLESINGER,
Secretary of Defense,
Washington, D.C.

DEAR MR. SECRETARY: In the absence of Senator Fulbright during the recess of the Senate I am enclosing copies of correspondence between him and Mr. Laird respecting Defense Department weather modification programs.

I would appreciate it if the Foreign Relations Committee could have a determination from the Department of Defense with respect to making this correspondence public.

Sincerely,

PAT M. HOLT.

GENERAL COUNSEL OF THE DEPARTMENT OF DEFENSE,
Washington, D.C., February 22, 1974.

Mr. PAT M. HOLT,
Chief of Staff,
Committee on Foreign Relations,
U.S. Senate,
Washington, D.C.

DEAR MR. HOLT: Secretary Schlesinger has asked that I respond to your letter of February 14, 1974 concerning correspondence between Mr. Laird and

The Department of Defense has reviewed this matter and it is our determination that the SECRET security classification originally applied to this correspondence is still appropriate.

Sincerely,

L. NIEDERLEHNER,
Acting General Counsel.

REASON FOR EXTRA SECRECY CONCERNING OPERATION

Senator PELL. There still may be no response, but I want to repeat my question. Do you have any idea or can you speculate as to the reason for the extra secrecy on this besides the interdiction factor, which I realize was classified.

Mr. DOOLIN. I speak in a personal capacity, and not in my official capacity, Mr. Chairman. I have been in this job for 5 years, and I didn't have this clearance even though Southeast Asia is in my area of responsibility in the Office of the Secretary of Defense. The first I learned of it was, as the result of a Jack Anderson column, and I made inquiries at the time—simply for my own edification—to find out if the rain that was artificially generated in a given area would deprive a friendly country also in the area of rain. For example, were we denying water to Thai rice paddies. I was told, no, that was not the case, that there was so much moisture in the air that you could not reduce the amount really in another area; and not to pursue the matter. It was an operation that was held in a special channel and access was very, very limited. I think, because of the perceived sensitivity of the operation.

Senator PELL. In retrospect, I think if this had been unclassified, there would have been far less feeling about it, but that I guess, is water over the dam.

CIVILIAN AUTHORITIES WHO APPROVED OPERATIONS

What civilian authorities approved these operations over the years 1966 to 1972?

Mr. DOOLIN. These operations were initially conceived by the Office of the Civilian Director of Defense Research and Engineering. They were then approved by the Secretary of Defense.

Senator PELL. What was that division again?

Mr. DOOLIN. The Director of Defense Research and Engineering, Dr. Foster, John Foster.

Senator PELL. Right.

Would that be Dr. Currie——

Mr. DOOLIN. It is now Dr. Currie.

Senator PELL. That is the same post.

Mr. DOOLIN. Yes.

Senator PELL. It would go directly from him to the Secretary of Defense.

Mr. DOOLIN. I don't know whether it went to the Joint Chiefs first but the Joint Chiefs obviously were in the chain.

Senator PELL. Right.

Mr. DOOLIN. But the approval authority in the Department was the Secretary of Defense.

From there it did go to the White House.

WHO WAS INFORMED IN STATE DEPARTMENT?

Senator PELL. Who was informed in the State Department? Was anyone informed?

General FURLONG. There were a few informed in the State Department. I cannot give you their names.

Senator PELL. The functions.

General FURLONG To the best of my knowledge the Under Secretary of State for Political Affairs was informed.

Senator PELL. Right.

General FURLONG. I cannot say whether that is the limit or not.

WAS ANYONE IN ACDA INFORMED?

Senator PELL. Was anyone in the ACDA informed about it?

General FURLONG. No.

Senator PELL. They were not.

WAS THIS ONLY CLASSIFIED WEATHER MODIFICATION OPERATION?

From what you said earlier, as I understand it, this is the only classified weather modification operation that has been carried out by the Government in the last 10 years. Would that be a correct statement, to the best of your knowledge?

General FURLONG. To the best of our knowledge.

Colonel SOYSTER. It is the only one, to my knowledge.

Senator PELL. To the best of your knowledge it was the only one.

Mr. DOOLIN. The only one.

Senator PELL. There were different code names, Operation Popeye and Operation Intermediary, Compatriot. Were they one and the same?

Mr. DOOLIN. They were one and the same.

Senator PELL. This was it.

Mr. DOOLIN. When the code names Compatriot and Intermediary were uncovered they were changed.

ENVIRONMENTAL WARFARE

Senator PELL. Is there a coordinated executive branch position on environmental warfare, not just weather modification, but the other means of environmental warfare?

Mr. DOOLIN. That is my understanding, there is not.

Senator PELL. The thing that concerns me is not rainmaking per se, but when you open that Pandora's box what comes out with it? Will we achieve a technique to be able to both create and point a hurricane or typhoon? Will we be able to do geophysical modification, put a charge under the surface and let the earthquake follow?

General FURLONG. The testimony you have already received is I believe from personnel more competent than anybody from the DOD. I don't think we can contribute to your record.

Senator PELL. Thank you.

As you know, Dr. MacDonald has seen what it was, not the state of the art now but what it conceivably could be.

DECLASSIFICATION OF PROJECT

I gather your personal views are that this project could be declassified without any great breach of national security?

Mr. DOOLIN. All I can say on that, sir, is that would be my recommendation to my superiors.

Senator PELL. Right.

WEATHER MODIFICATION STUDY

Are you familiar with the study presently going on on the subject of weather modification, in which the Department is engaged as the lead agency?

Mr. DOOLIN. I am aware of a study that is being done for the White House.

Senator PELL. That is right.

Mr. DOOLIN. That includes some items such as that, yes.

Senator PELL. Yes.

When do you expect that study to be finished?

Mr. DOOLIN. I checked on that today, Mr. Chairman, and the estimate is it will be another 2 weeks or so before it is available for consideration in the DOD and then for transmittal to the White House.

Senator PELL. It will be another 2 weeks before pulled together by DOD.

Mr. DOOLIN. Yes, sir.

Senator PELL. What classification will that study have?

Mr. DOOLIN. I do not know, sir.

Senator PELL. You do not know.

Mr. DOOLIN. I am not involved in the preparation of that study.

Senator PELL. Right. The reason I am raising these questions is. that this bears directly on my proposed weather modification treaty When that study is in, we want to have another meeting with the Defense Department and the executive branch to discuss it.

Mr. DOOLIN. Mr. Chairman, this will be, of course, a report transmitted to the President at his request,, so we would not have any control over its dissemination other than to the President.

Senator PELL. Senator Case, I have a series of other specific questions. Any time you wish to ask some, go ahead.

Senator CASE. Go ahead, Mr. Chairman, you are covering much of the ground I was interested in.

Senator PELL. I have already taken up my 10 minutes.

CHANNEL OF APPROVAL OF OPERATIONS

Senator CASE. There were two questions suggested here, following the chairman's inquiry. Would you specify the precise channel for the approval of the operations?

General FURLONG. Yes, sir.

Senator PELL. Excuse me. Do you mean the other departments that are involved?

Senator CASE. Yes, and the Defense Department, too.

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THOSE WHO KNEW ABOUT PROGRAMS

And then a list of all of those who knew about the programs if you can.

Mr. DOOLIN. There were over 1,400 people at one time that did have this clearance including the men who flew the missions. I think it would be very difficult to compile.

Senator CASE. If not by name, give us a list by category, if you will, so we can see who had knowledge.

Mr. DOOLIN. We will do that, sir.

[The information referred to follows:]

PERSONNEL INFORMED OF OPERATION AND ITS SCOPE

[Supplied by Department of Defense]

The following categories of personnel were informed in varying degrees as to the operation and its scope:

White House
Congress of the U.S.—Chairmen of DoD Jurisdictional Committees
Secretary of Defense
Deputy Secretary of Defense
Director of Defense Research and Engineering
Limited members of the staff of the Office of the Secretary of Defense
The Joint Chiefs of Staff
Commander-in-Chief Pacific
Commander, US Military Assistance Command, Vietnam
Commander 7AF
Limited members of staff supporting these officers
Operational crews and supporting personnel
Secretary of State and limited supporting staff
Director CIA and limited supporting staff

DoD can verify that information was given to its personnel and the Chairman of its Jurisdictional Committees. Categories of non DoD personnel listed represent DoD's best estimate of those informed.

APPROVAL BY OR DISCUSSION WITH CONGRESSIONAL COMMITTEES

Senator CASE. Was it ever approved by any congressional committee or discussed with any congressional committee?

General FURLONG. Preceding testimony has shown four committee chairman were informed. We have nothing to add to the information already provided to the committee.

Senator CASE. Was that as a part of an oversight operation of some sort?

General FURLONG. No, sir. It was not done on a recurring basis.

Senator CASE. You just told four committee chairmen at a particular time.

General FURLONG. Yes, sir, that is correct.

Senator CASE. What were they? The Armed Services Committees—

General FURLONG. Yes, sir, the Armed Services and Appropriations Committees.

Senator CASE. That only let Democrats in, didn't it?

[Laughter.]

Senator PELL. That is when it occurred in North Vietnam.

Senator CASE. Thank you, Mr. Chairman, go ahead.

WHITE HOUSE KNOWLEDGE, APPROVAL, OR CLEARANCE

Senator PELL. As I say, I think you may have exaggerated the importance of the program. Who knew about it or gave the approval or cleared it in the White House? Could you submit for the record a list of the people?

Mr. DOOLIN. No, sir, I do not believe we can.

Senator PELL. Why?

Mr. DOOLIN. I know that information on this operation was sent to the White House. Whether it was for information or whether it was for approval, I do not know. I have been unable to find out.

Senator PELL. I realize you may have problems in trying it again. Could you try once more and submit for the record at the committee's request those who approved it at the White House and also for the record the list of other officials?

Mr. DOOLIN. We will try again, Mr. Chairman, because—we did try—because we wanted to be as fully responsive as we could be today, but unfortunately some of the principals who were involved at the time are dead.

[As of the date of publication, the information referred to had not been supplied.]

DOD POSITION AT STOCKHOLM CONFERENCE

Senator PELL. Both Senator Case and I were at the Stockholm Conference on Environment. There was a tremendous flap there over the question of ecological warfare and weather modification. I remember the DOD representative, took a very strong position on the question of reporting weather and environmental activities to other governments. It was a mandatory provision in the first draft of the U.N. resolution. The DOD took a very strong position in that conference that it be changed to "whenever feasible."

What was the reason for the position of the Defense Department? I cannot understand why they are so concerned.

Mr. DOOLIN. I would not be competent to answer that. I really cannot go beyond what Mr. Forman has said on previous occasions.

Senator PELL. You read his testimony. He was very unforthcoming basically.

Mr. DOOLIN. I read the transcript of your last hearing, sir, partially to educate myself for this meeting.

COORDINATION OF OPERATIONS

Senator PELL. Going to the question of the coordination of these operations, you say the State Department was informed but you did not necessarily coordinated with them.

General FURLONG. I don't think we ought to characterize the nature of that, sir. I am not confident which phrase is the correct description.

WERE THAI AND LOA GOVERNMENTS INFORMED?

Senator PELL. Were the Governments of Thailand and Laos, both of which countries were involved, informed about these operations?

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Mr. Doolin. The Royal Lao Government had given approval for interdiction efforts against the trail system and we considered this to be part of the interdiction effort.

The Royal Thai Government to my understanding was not informed.

OTHER WEATHER MODIFICATION PROGRAMS

Senator Pell. Since the secrecy of this program is held so tightly, do you think there could be other weather modification programs going on now in the Government of which you are not aware?

I am not asking this facetiously. I just don't know.

Mr. Doolin. It is possible, but I would think not. We have a Presidential decision of 2 years ago on weather modification. Only two foreign weather modification projects have been approved since then—one with regard to Panama to keep the canal clear of fog, and the other was a drought relief operation in the Azores.

Senator Pell. We used it also, I thought, on a friendly basis with other countries for clearing airfields and so forth.

Mr. Doolin. Those, sir, as I understand it, are the only two since the Presidential decision a few years ago. Before that, for example, we operated on Okinawa for drought relief. We assisted the Philippines at one time. Since the decision, as I understand it, there was a request from some of the Sahelian states in Africa. Our position has been that the technology is available through commercial contractors and therefore we have advised the countries to go to a commercial contractor for assistance in this regard.

Senator Pell. Have the armed services provided support or training or equipment in this regard to any foreign groups or any foreign governments or troops?

Colonel Kaehn. To some degree there has been interest shown by the Philippines in the techniques, the R. & D. we have done, and the methodology. The apparatus is commercially available.

Senator Pell. It is unclassified anyway, the research.

Colonel Kaehn. Exactly.

Senator Pell. And there is no law against it as of now in any case, either.

Colonel Kaehn. No, sir, not to the best of my knowledge.

Senator Pell. As far as you know, then we have not conducted any weather modification activity over Cuba?

Mr. Doolin. No, sir.

Senator Pell. The only ones we have done are in this part of the world?

Mr. Doolin. Yes, sir.

NSC INTERAGENCY PANEL

Senator Pell. In 1972 there was an NSC interagency panel under the chairmanship of Mr. Pollack to study the problems of weather modification, to formula American policy.

Did you have a representative on that panel?

Colonel Kaehn. Yes.

Senator Pell. Were you he?

Colonel Kaehn. No, I was not.

Senator Pell. Who was the representative?

Colonel KAEHN. The representative in 1972 was from the office of the Assistant Secretary of Defense for ISA [International Security Affairs]. That is the Under Secretary's committee's report which was produced 2 years ago, you are talking about?

Mr. DOOLIN. That would not have been my office, but the Deputy Assistant Secretary of Defense for Policy Plans, and NSC Affairs.

Senator PELL. It would not have been you, then?

Mr. DOOLIN. No, sir, but it would have been from the Office of Assistant Secretary of Defense for International Security Affairs.

NSC INTERAGENCY PANEL'S REPORT

Senator PELL. Are you at liberty to recall when the final report was made by this panel and what the classification is of that report?

Colonel KAEHN. If we are talking about the same one ——

Senator PELL. I am talking about the one the Pollack Panel did. He was the chairman of it in 1972.

Colonel KAEHN. Yes.

Senator PELL. On this general field.

Colonel KAEHN. That report was submitted in the spring of 1972.

Senator PELL. That would be the one.

Do you recall the classification?

Colonel KAEHN. Yes. As I recall the classification was "Secret."

Senator PELL. "Secret." Would you be at liberty to tell us or can you recall the recommendations and findings of that report?

Colonel KAEHN. Without it in front of me, sir, I would rather not.

Senator PELL. I understand.

Perhaps you could look it up for the record. We are not asking for the whole report.

Mr. DOOLIN. I wonder if Mr. Chapin could be of any assistance?

Mr. CHAPIN. I do not know. I would like to look it up. I would prefer to verify the classification.

Senator PELL. All right.

Would you make note of our request that we receive the conclusions and recommendations of that report and give us something on that?

In fact, we would like to have for our file, unless there is some reason against it, and naturally observing its classification, a copy of them.

[As of the date of publication, the information referred to had not been supplied.]

DECLASSIFICATION OF SECRETARY LAIRD'S LETTER

Going for a second to Secretary Laird's letter, you are going to take that under advisement. My view would be that you would declassify the whole business.

Mr. DOOLIN. The specific matter of Mr. Laird's letter would depend on the decision that was made on the larger item.

PROPOSED DRAFT TREATY

Senator PELL. Are you at liberty to express a view with regard to our proposed draft treaty, what its effect would be on the Defense Department, your plans in being? Would it in any way inhibit you?

Mr. DOOLIN. Mr. Chairman, it is just not in my area of competence. I was here just in context of a briefing on the operations in Southeast Asia which is my area. I have my personal views on rainmaking, but I think you have had plenty of experts speak to you on that.

HEAVY FLOODING IN NORTH VIETNAM

Senator PELL. Was there any relationship between the rainmaking that went on in Southeast Asia and the extraordinarily high floods that occurred at that time in North Vietnam?

Mr. DOOLIN. There were not, sir. At the time of the heavy flooding in North Vietnam there were no rainmaking operations conducted. As Lieutenant Colonel Soyster said in his briefing, in the cases where adequate rainfall did occur then the seeding would have been superfluous and possibly counterproductive. Seeding could have destroyed the clouds. The flooding in North Vietnam, as you will recall, generated widespread civilian suffering and that was never the intention nor the result of this program. Rainmaking in this case would have not only been inappropriate, but also would have been prohibited by the standing orders.

NOVEMBER 1, 1968, PROHIBITION OF RAINMAKING OVER NORTH VIETNAM

Senator PELL. Why on November 1, 1968, was rainmaking over North Vietnam prohibited and never reinstituted? What was the reason for that date?

Mr. DOOLIN. I cannot speak for the administration.

General FURLONG. That was the day President Johnson announced the bombing halt. This fit in with the bombing halt. When you stopped operations in North Vietnam this operation was included as well.

Senator PELL. Right. Didn't we resume bombing of North Vietnam?

Mr. DOOLIN. Yes, sir.

Senator PELL. But these weather modifications were never resumed.

General FURLONG. No, sir.

EFFECTIVENESS OF PROGRAM

Senator PELL. What is your general view as to the effectiveness of this program? I gather from the testimony that you believe it did work and accomplished the purpose you wished.

Mr. DOOLIN. Again, I am not a scientist. I would go back to your elephant-mouse analogy. When you look at those isolines, and the amount of rainfall that was in these given areas anyway, and what was added to it possibly by these extra seedings, it looks to me like when you are getting 21 inches in a given area, and we add 2 inches, if I was on the bottom, I do not think I would know the difference between 21 and 23.

Senator PELL. Was that opinion shared in by the military?

Mr. DOOLIN. I cannot say.

Colonel SOYSTER. It was one of the most difficult parts of the project to try to quantify how well we were doing. The reports indicated we were able to induce rainfall and we knew that from other projects.

The quantification of it was the difficult portion.

OTHER PROGRAMS BEING WORKED ON

Senator PELL. Are you familiar with any other programs we are working on now using rainmaking or, to clear fog from airports and for rescue operations? Do they come under your office?

Colonel SOYSTER. Not under mine, sir.

Colonel Kaehn may be able to speak to that.

Colonel KAEHN. Are you talking about clearing of fog in airports, sir?

Senator PELL. Yes.

Colonel KAEHN. I can speak to that from an R. & D. standpoint.

Senator PELL. And also from the standpoint of rescuing people.

Colonel KAEHN. There are two types of fog to deal with: one is called cold fog where the water exists at temperatures below freezing; it actually exists in water from below zero degrees centigrade: that is commonly called cold fog. We have demonstrated in the R. & D. sense the feasibility of eliminating this fog and we have attempted it at places like Elmendorf, Alaska, so you can get a C–141 in and out of there.

We have a more vexing problem, though, in the handling of warm fog. This is a more difficult problem considerably and one which we continue to do research and development work on.

The Navy is particularly interested in marine fog, the kind of fog that the Navy would encounter in its global mission at sea when it goes everywhere from the Polar to tropical meterological regimes, and encounters different variations.

Senator PELL. Which is your office?

Colonel KAEHN. I am in the Office of the Director of Defense Research and Engineering.

Senator PELL. Are you aware of any other research that we are doing now with regard to other forms of weather modification for military reasons?

Colonel KAEHN. No, sir. To the best of my knowledge, the three main thrusts are the cold fog, warm fog, and the cumulus cloud work.

Senator PELL. You are not working on any of these far out thoughts that have been brought out in testimony before? You are not working on any of those projects at this time?

Colonel KAEHN. No, sir.

Senator PELL. The development of typhoons or the creation of earthquakes or the melting of the Greenland Icecap, anything of that sort?

Colonel KAEHN. No, sir.

Senator PELL. Obviously melting the Greenland Icecap would be very disadvantageous for us.

Mr. DOOLIN. That would really be what you would call climate modification rather than weather modification.

Senator PELL. Exactly.

Colonel KAEHN. The lead agency in the tropical storm modification program is the Department of Commerce: the program is called Stormfury.

In the past the Department of Defense has provided assets to Commerce to do the seeding work since we have the airframes to help them conduct the program. But the lead agency in that effort is the Department of Commerce.

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WEATHER MODIFICATION INFORMATION SOUGHT BY POLLACK COMMITTEE

Senator PELL. I would like to go back for a second to a previous question. The National Security Council Interagency Panel, the Pollack committee, was seeking information on military weather modification in Southest Asia. Do you know if it was denied information by the Department of Defense in this area or can you recall that?

Colonel KAEHN. Sir, that was prior to my arrival in the Pentagon and I would rather research that.

Senator PELL. Could you, and submit it for the record.

In other words, I have three questions to ask you for the record in this regard: Did the Pollack committee seek information on weather modification in Southeast Asia? That is question No. 1. Was this information denied an agency of the Government. That is Question No. 2. If there was any denial of it, why was the committee denied this access? What was the reason for it? That is Question No. 3. These answers may all be very simple, but I do feel compelled to ask the questions.

[The information refered to follows:]

POLLACK COMMITTEE'S SEEKING OF INFORMATION ON WEATHER MODIFICATION IN SOUTHEAST ASIA

[Supplied by Department of Defense]

Question 1. Did the Pollack Committee seek information on weather modification in Southeast Asia?

Answer. Yes.

Question 2. Was this information denied an agency of the Government?

Answer. Yes.

Question 3. If there was any denial of it, why was the committee denied this access; what was the reason for it.

Answer. Classification then assigned to this information precluded its availability.

HAS DEPARTMENT OF DEFENSE WORKED WITH CENTRAL INTELLIGENCE AGENCY?

Have you worked at all with the Central Intelligence Agency in trying to carry out weather modification activities or was this completely a Department of Defense operation?

Mr. DOOLIN. Within the operations that were performed in Southeast Asia?

Senator PELL. That is right.

Mr. DOOLIN. This was the only time such an operation was carried out. It was done by the U.S. Air Force.

General FURLONG. This was all Department of Defense.

Senator PELL. Not the Central Intelligence Agency.

IS THIS ONLY U.S. MILITARY WEATHER MODIFICATION ACTIVITY?

Is this the only weather modification activity that the U.S. Government has carried out for military reasons?

Mr. DOOLIN. We can only speak to what the Department of Defense did.

Senator PELL. I see.

Mr. DOOLIN. But, to the best of our knowledge, this is the only weather modification activity conducted by the Department of Defense that was classified.

We are aware of a series that were unclassified.

Senator PELL. Senator Case.

Senator CASE. No more, thanks, I think you have covered it.

DECLASSIFICATION RECOMMENDED

Senator PELL. I must say in conclusion that my own strong recommendation and thought is that you ought to declassify this, and we will ask you to declassify. We will keep your confidence, but you should give us your permission to declassify and publish today's hearing and the whole program because I think it would restore a great deal of confidence, not only in America, but around the world, in the intentions and capacities of the U.S. Government in this regard. There is nothing I can think of that we have said here today which, if published in the public press, would be of any harm. But we will leave that to you and your Department, keeping your confidence, although the Laird letter is slipping away out of our control because it seems to be known around town.

Mr. DOOLIN. Mr. Hersh has been trying to get ahold of me, from the New York Times, and I understand he would have been a better witness before you today than I am. [Laughter.]

Senator PELL. I thank you very much for your frankness and candor and your willingness to be with us. As I say, I hope you will very quickly look into this question of permitting this transcript to be released and the program to be released.

You have been hung for worse things than this, and if people knew what this was, all the people would——

Mr. DOOLIN. We will try our best.

POTENTIAL ADVISABILITY OF WEATHER MODIFICATION TREATY

Senator PELL. Are any of you willing to advance a personal view with regard to the potential advisability of our weather modification treaty, or do you not feel in a position to do so?

Mr. DOOLIN. Well, as I said, all I can really speak to is the rainmaking aspect of it. If an adversary wanted to stop me from getting from point A to point B so I could do something at point B, I would rather he stopped me with a rainstorm than stopped me with a bunch of bombs. Frankly, I view this in that context as really quite humane, if it works.

In my own mind on the basis of the material that I have seen, I am not convinced that it had anything more than a marginal effect, but that is something that even the experts disagree on.

OPERATION ROME PLOW

Senator PELL. As you know, Operation Rome Plow stripped the green cover in Vietnam——

Mr. DOOLIN. To create the landing zones.

Senator PELL [continuing]. To create the landing zones and also make it more militarily controllable. That has resulted in a degree of climate modification...

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Mr. DOOLIN. The Rome Plow?

Senator PELL. Yes.

Mr. DOOLIN. I know in some areas it was necessary to use Rome Plow for reasons of urgent military necessity for clearing roads or an HLZ, helicopter landing zone, for example. The Rome Plow was not generally used in the context of expanding perimeter security. I may be wrong, but that was done primarily around fire bases, by the use of defoliants and active patrolling and not by Rome Plow.

Colonel SOYSTER. In my experience in Vietnam, which included a lot of perimeter defense, we did not have the equipment to do it. I never saw it in 10 months in Vietnam.

EFFECT OF VIETNAM WAR ON VIETNAM

Senator PELL. I think the effect of the war, as I understand it, not having been to Vietnam in the past few years, has been to radically change the character of the country and some of the climate of the country because the green cover has been eliminated. Obviously, these bomb hollows scattered over the country change the character of the country.

Mr. DOOLIN. I think you have to discriminate rather carefully there, Senator, as to what areas of Vietnam you are addressing. I have just returned from a—albeit much too brief—visit to Vietnam with Deputy Secretary Rush. I have made countless visits to Vietnam; I must say it is now the Vietnam I remember from the early 1950's. Saigon again looks like a Vietnamese city. The streets are being cleaned. The buildings are being painted. The bars are being shut down. There are no GI's running around.

The Delta exhibited an incredible prosperity. Aside from the money problems they have—inflation in the major cities which I think can be easily controlled if they get a handle on their commodity imports—the average farmer in the Delta is doing very, very well.

I think that the areas that you are talking about are primarily in the highlands.

Senator PELL. In the highlands, in the north.

Mr. DOOLIN. And in northwest MR–1, which are areas that basically are not considered part of Vietnam in the sense of the real vital living Vietnam even by the Vietnamese themselves.

General FURLONG. Mr. Chairman, one other thing that you might have your staff look at for you and that is the National Academy of Sciences report on herbicides. One of its findings addresses climatological modification resulting from defoliation. I believe it is their conclusion that that is not the case.

Mr. DOOLIN. In fact, I received a request, sir, if I recall, it was about 2 years ago by a team that went out there to study the effects of herbicides in Vietnam, and they went to an area that had been fairly extensively sprayed with herbicide, and they could find no lasting damage, and they requested permission from us to provide them with herbicides so they could respray it and take a look at it, and we told them no.

Senator PELL. I thank you.

DECLASSIFICATION OF PROGRAM

I don't mean to divert from the subject at hand, but I thank you for the testimony. If I get queried by the press, I will relay to them what I have said to you, that I would urge you to declassify the whole program, that perhaps the secrecy has been exaggerated, and that I have not been able to ascertain a reason for this tremendous secrecy. I do not think anybody in this room understands the extrasensitivity for this program.

Senator CASE. It is the kind of thing that you maybe never will know, and maybe they won't, either.

[Discussion off the record.]

DROPPING OF EMULSIFIERS ON LAO PANHANDLE

Senator PELL. One final and specific query here. Do you know anything about the dropping of emulsifiers on trails in the Loatian Panhandle?

Mr. DOOLIN. I do not.

General FURLONG. I heard there was to have been such a proposal. I have heard that it did not work very well and that we did not do any more of it. I do not think it was done by the DOD.

Senator PELL. What it basically does, I understand, is to make the trails slippery and impossible.

General FURLONG. Yes, sir.

Senator PELL. So it may have been attempted, but it was not under the Defense Department's jurisdiction.

General FURLONG. No, sir. First of all, it just would not work, and secondly, it would be dangerous for the crews, and third, we did not want to do it.

Senator PELL. Why would it be dangerous for the crews?

General FURLONG. Because if you were to do something effective, you are talking about lots of pounds of emulsifier. It is the kind of thing that takes a lot of poundage, and you have limited access to some fairly confined area in something like a C-130. As a former C-130 pilot, I would be less than enthused at flying low level over the Laotian Panhandle and shoveling out emulsifier. It just doesn't turn me on. I think sound military judgment prevailed and came to the same conclusion.

Senator PELL. Thank you. I thank you very much indeed and thank you for your frankness and for your being here.

The subcommittee will adjourn, subject to the call of the Chair.

[Whereupon, at 3:35 p.m., the subcommittee adjourned, subject to the call of the Chair.]

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APPENDIX 10

X, 2

Telegraph.co.uk

'How we made the Chernobyl rain'

By Richard Gray
Published: 12:01AM BST 22 Apr 2007

Russian military pilots have described how they created rain clouds to protect Moscow from radioactive fallout after the Chernobyl nuclear disaster in 1986.

Major Aleksei Grushin repeatedly took to the skies above Chernobyl and Belarus and used artillery shells filled with silver iodide to make rain clouds that would "wash out" radioactive particles drifting towards densely populated cities.

Related Articles

Kremlin revives plan for 60-mile tunnel to Alaska (/news/worldnews/1549192/Kremlin-revives-plan-for-tunnel-to-Alaska.html)

Britain still affected by Chernobyl (/news/uknews/1514492/20-years-on-Britain-still-feels-the-effects-of-Chernobyl.html)

Chernobyl protesters jailed (/news/worldnews/europe/belarus/1488881/Chernobyl-protesters-are-jailed.html)

More than 4,000 square miles of Belarus were sacrificed to save the Russian capital from the toxic radioactive material.

"The wind direction was moving from west to east and the radioactive clouds were threatening to reach the highly populated areas of Moscow, Voronezh, Nizhny Novgorod, Yaroslavl," he told Science of Superstorms, a BBC2 documentary to be broadcast today.

"If the rain had fallen on those cities it would've been a catastrophe for millions. The area where my crew was actively influencing the clouds was near Chernobyl, not only in the 30km zone, but out to a distance of 50, 70 and even 100 km."

In the wake of the catastrophic meltdown of the Chernobyl nuclear reactor, people in Belarus reported heavy, black-coloured rain around the city of Gomel. Shortly beforehand, aircraft had been spotted circling in the sky ejecting coloured material behind them.

Moscow has always denied that cloud seeding took place after the accident, but last year on the 20th anniversary of the disaster, Major Grushin was among those honoured for bravery. He claims he received the award for flying cloud seeding missions during the Chernobyl clean-up.

A second Soviet pilot, who asked not to be named, also confirmed to the programme makers that cloud seeding operations took place as early as two days after the explosion.

Alan Flowers, a British scientist who was one of the first Western scientists allowed into the area to examine the extent of radioactive fallout around Chernobyl, said that the population in Belarus was exposed to radiation doses 20 to 30 times higher than normal as a result of the rainfall, causing intense radiation poisoning in children.

Mr Flowers was expelled from Belarus in 2004 after claiming that Russia had seeded the clouds. He said: "The local population say there was no warning before these heavy rains and the radioactive fallout arrived."

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APPENDIX 11

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U.S. Patent No. 4,686,605

United States Patent [19]

Eastlund

[11] Patent Number: 4,686,605

[45] Date of Patent: Aug. 11, 1987

[54] METHOD AND APPARATUS FOR ALTERING A REGION IN THE EARTH'S ATMOSPHERE, IONOSPHERE, AND/OR MAGNETOSPHERE

[75] Inventor: Bernard J. Eastlund, Spring, Tex.

[73] Assignee: APTI, Inc., Los Angeles, Calif.

[21] Appl. No.: 690,333

[22] Filed: Jan. 10, 1985

[51] Int. Cl.⁴ H05B 6/64; H05C 3/00; H05H 1/46

[52] U.S. Cl. .... 361/231; 89/1.11; 380/59; 244/158 R

[58] Field of Search .... 361/230, 231; 244/158 R; 376/100; 89/1.11; 380/59

[56] References Cited

PUBLICATIONS

Liberty Magazine. (2/35) p. 7 N. Tesla.
New York Times (9/22/40) Section 2, p. 7 W. L. Laurence.
New York Times (12/8/15) p. 8 Col. 3.

Primary Examiner—Salvatore Cangialosi
Attorney, Agent, or Firm—Roderick W. MacDonald

[57] ABSTRACT

A method and apparatus for altering at least one selected region which normally exists above the earth's surface. The region is excited by electron cyclotron resonance heating to thereby increase its charged particle density. In one embodiment, circularly polarized electromagnetic radiation is transmitted upward in a direction substantially parallel to and along a field line which extends through the region of plasma to be altered. The radiation is transmitted at a frequency which excites electron cyclotron resonance to heat and accelerate the charged particles. This increase in energy can cause ionization of neutral particles which are then absorbed as part of the region thereby increasing the charged particle density of the region.

15 Claims, 5 Drawing Figures

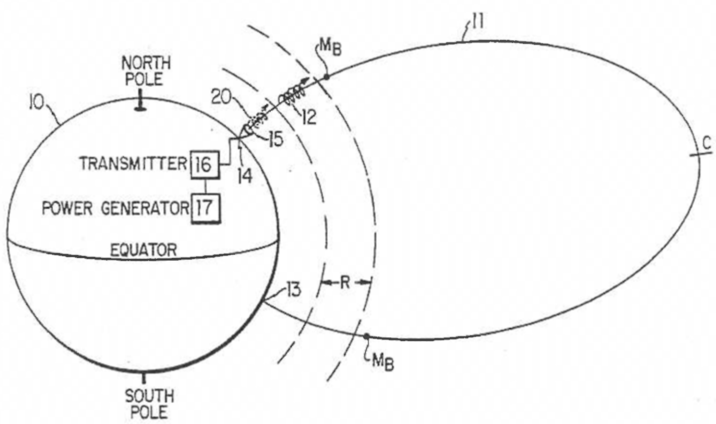

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FIG. 1

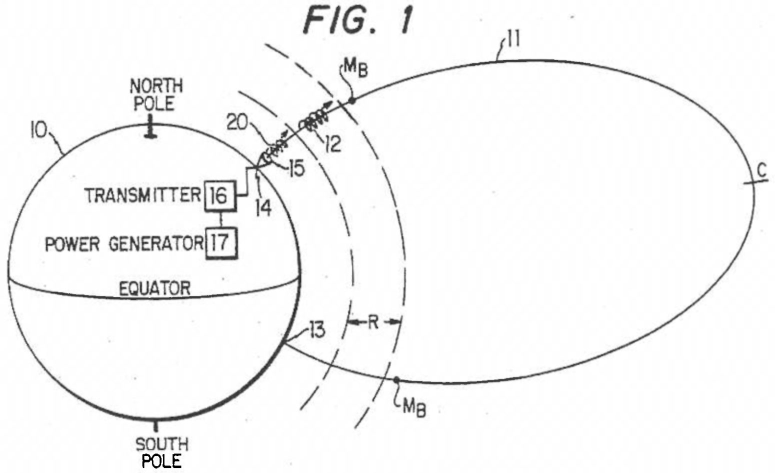


FIG. 2

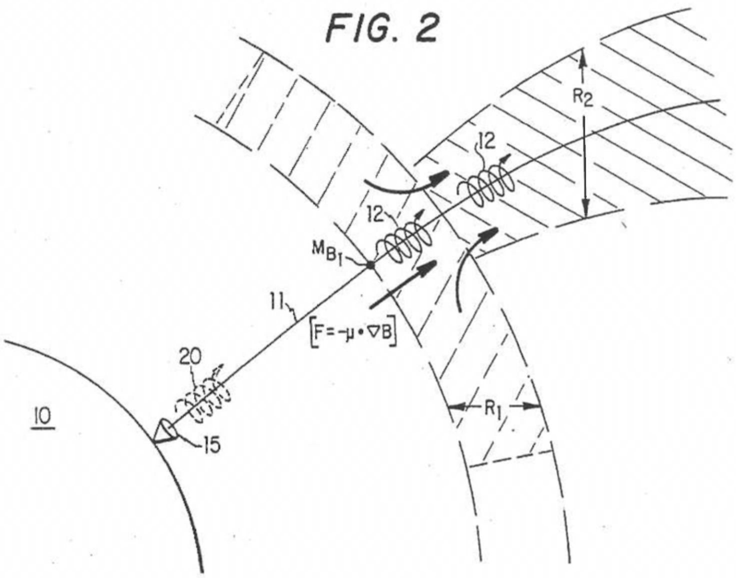
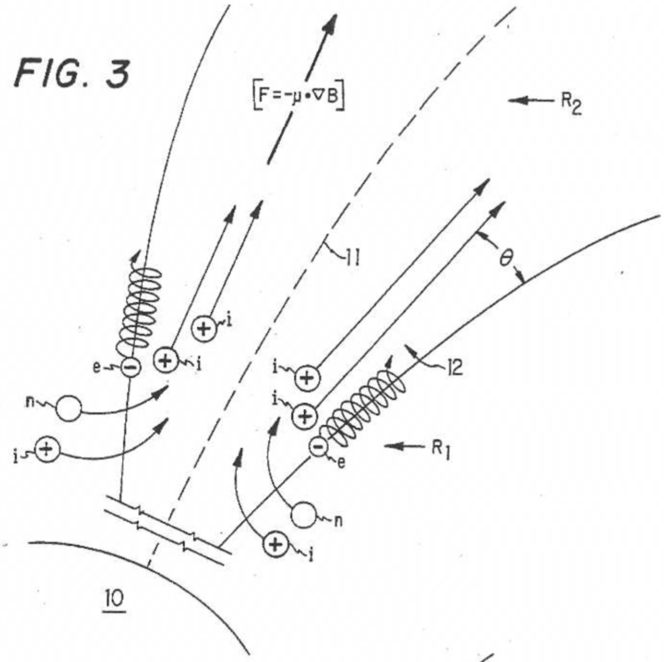


FIG. 3



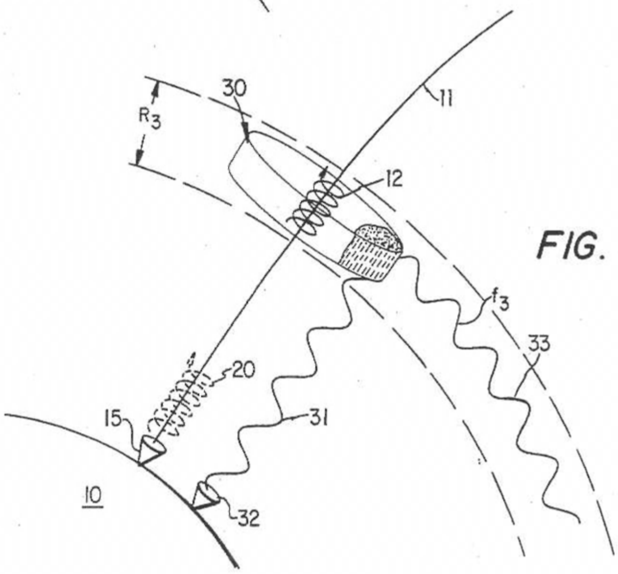
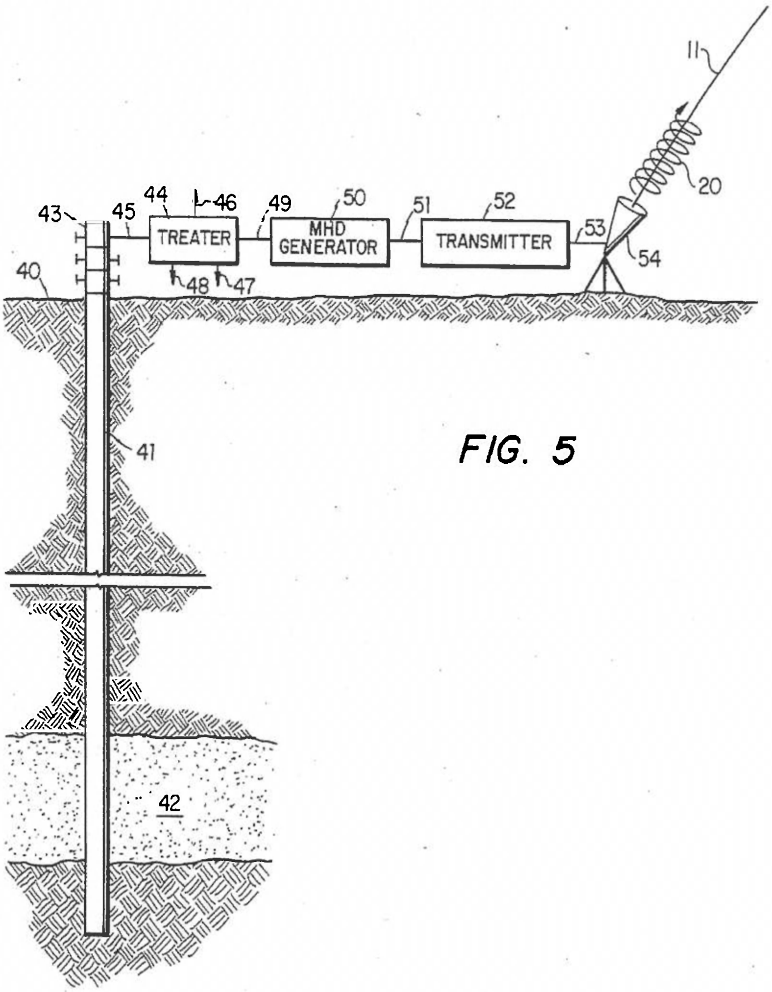


FIG. 4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TREATER
MHD GENERATOR
TRANSMITTER
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FIG. 5

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METHOD AND APPARATUS FOR ALTERING A REGION IN THE EARTH'S ATMOSPHERE, IONOSPHERE, AND/OR MAGNETOSPHERE

DESCRIPTION

1. Technical Field

This invention relates to a method and apparatus for altering at least one selected region normally existing above the earth's surface and more particularly relates to a method and apparatus for altering said at least one region by initially transmitting electromagnetic radiation from the earth's surface essentially parallel to and along naturally-occurring, divergent magnetic field lines which extend from the earth's surface through the region or regions to be altered.

2. Background Art

In the late 1950's, it was discovered that naturally-occuring belts exist at high altitudes above the earth's surface, and it is now established that these belts result from charged electrons and ions becoming trapped along the magnetic lines of force (field lines) of the earth's essentially dipole magnetic field. The trapped electrons and ions are confined along the field lines between two magnetic mirrors which exist at spaced apart points along those field lines. The trapped electrons and ions move in helical paths around their particular field lines and "bounce" back and forth between the magnetic mirrors. These trapped electrons and ions can oscillate along the field lines for long periods of time.

In the past several years, substantial effort has been made to understand and explain the phenomena involved in belts of trapped electrons and ions, and to explore possible ways to control and use these phenomena for beneficial purposes. For example, in the late 1950's and early 1960's both the United States and U.S.S.R. detonated a series of nuclear devices of various yields to generate large numbers of charged particles at various altitudes, e.g., 200 kilometers (km) or greater. This was done in order to establish and study artifical belts of trapped electrons and ions. These experiments established that at least some of the extraneous electrons and ions from the detonated devices did become trapped along field lines in the earth's magnetosphere to form artificial belts which were stable for prolonged periods of time. For a discussion of these experiments see "The Radiation Belt and Magnetosphere", W. N. Hess, Blaisdell Publishing Co., 1968, pps. 155 et sec.

Other proposals which have been advanced for altering existing belts of trapped electrons and ions and/or establishing similar artificial belts include injecting charged particles from a satellite carrying a payload of radioactive beta-decay material or alpha emitters; and injecting charged particles from a satellite-borne electron accelerator. Still another approach is described in U.S. Pat. No. 4,042,196 wherein a low energy ionized gas, e.g., hydrogen, is released from a synchronous orbiting satellite near the apex of a radiation belt which is naturally-occurring in the earth's magnetosphere to produce a substantial increase in energetic particle precipitation and, under certain conditions, produce a limit in the number of particles that can be stably trapped. This precipitation effect arises from an enhancement of the whistler-mode and ion-cyclotron mode interactions that result from the ionized gas or "cold plasma" injection.

It has also been proposed to release large clouds of barium in the magnetosphere so that photoionization will increase the cold plasma density, thereby producing electron precipitation through enhanced whistler-mode interactions.

However, in all of the above-mentioned approaches, the mechanisms involved in triggering the change in the trapped particle phenomena must be actually positioned within the affected zone, e.g., the magnetosphere, before they can be actuated to effect the desired change.

The earth's ionosphere is not considered to be a "trapped" belt since there are few trapped particles therein. The term "trapped" herein refers to situations where the force of gravity on the trapped particles is balanced by magnetic forces rather than hydrostatic or collisional forces. The charged electrons and ions in the ionosphere also follow helical paths around magnetic field lines within the ionosphere but are not trapped between mirrors, as in the case of the trapped belts in the magnetosphere, since the gravitational force on the particles is balanced by collisional or hydrostatic forces.

In recent years, a number of experiments have actually been carried out to modify the ionosphere in some controlled manner to investigate the possibility of a beneficial result. For detailed discussions of these operations see the following papers: (1) Ionospheric Modification Theory; G. Meltz and F. W. Perkins; (2) The Platteville High Power Facility; Carrol et al.; (3) Arecibo Heating Experiments; W. E. Gordon and H. C. Carlson, Jr.; and (4) Ionospheric Heating by Powerful Radio Waves; Meltz et al., all published in Radio Science, Vol. 9, No. 11, November, 1974, at pages 885-888; 889-894; 1041-1047; and 1049-1063, respectively, all of which are incorporated herein by reference. In such experiments, certain regions of the ionosphere are heated to change the electron density and temperature within these regions. This is accomplished by transmitting from earth-based antennae high frequency electromagnetic radiation at a substantial angle to, not parallel to, the ionosphere's magnetic field to heat the ionospheric particles primarily by ohmic heating. The electron temperature of the ionosphere has been raised by hundreds of degrees in these experiments, and electrons with several electron volts of energy have been produced in numbers sufficient to enhance airglow. Electron concentrations have been reduced by a few percent, due to expansion of the plasma as a result of increased temperature.

In the Elmo Bumpy Torus (EBT), a controlled fusion device at the Oak Ridge National Laboratory, all heating is provided by microwaves at the electron cyclotron resonance interaction. A ring of hot electrons is formed at the earth's surface in the magnetic mirror by a combination of electron cyclotron resonance and stochastic heating. In the EBT, the ring electrons are produced with an average "temperature" of 250 kilo electron volts or kev (2.5×10^9K) and a plasma beta between 0.1 and 0.4; see, "A Theoretical Study of Electron—Cyclotron Absorption in Elmo Bumpy Torus", Batchelor and Goldfinger, Nuclear Fusion, Vol. 20, No. 4 (1980) pps. 403-418.

Electron cyclotron resonance heating has been used in experiments on the earth's surface to produce and accelerate plasmas in a diverging magnetic field. Kosmahl et al. showed that power was transferred from the electromagnetic waves and that a fully ionized plasma

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was accelerated with a divergence angle of roughly 13 degrees. Optimum neutral gas density was 1.7×10^{14}per cubic centimeter; see, "Plasma Acceleration with Microwaves Near Cyclotron Resonance", Kosmahl et al., Journal of Applied Physics, Vol. 38, No. 12, Nov., 1967, pps. 4576–4582.

DISCLOSURE OF THE INVENTION

The present invention provides a method and apparatus for altering at least one selected region which normally exists above the earth's surface. The region is excited by electron cyclotron resonance heating of electrons which are already present and/or artifically created in the region to thereby increase the charged particle energy and ultimately the density of the region.

In one embodiment this is done by transmitting circularly polarized electromagnetic radiation from the earth's surface at or near the location where a naturally-occurring dipole magnetic field (force) line intersects the earth's surface. Right hand circular polarization is used in the northern hemisphere and left hand circular polarization is used in the southern hemisphere. The radiation is deliberately transmitted at the outset in a direction substantially parallel to and along a field line which extends upwardly through the region to be altered. The radiation is transmitted at a frequency which is based on the gyrofrequency of the charged particles and which, when applied to the at least one region, excites electron cyclotron resonance within the region or regions to heat and accelerate the charged particles in their respective helical paths around and along the field line. Sufficient energy is employed to cause ionization of neutral particles (molecules of oxygen, nitrogen and the like, particulates, etc.) which then become a part of the region thereby increasing the charged particle density of the region. This effect can further be enhanced by providing artificial particles, e.g., electrons, ions, etc., directly into the region to be affected from a rocket, satellite, or the like to supplement the particles in the naturally-occurring plasma. These artificial particles are also ionized by the transmitted electromagnetic radiation thereby increasing charged particle density of the resulting plasma in the region.

In another embodiment of the invention, electron cyclotron resonance heating is carried out in the selected region or regions at sufficient power levels to allow a plasma present in the region to generate a mirror force which forces the charged electrons of the altered plasma upward along the force line to an altitude which is higher than the original altitude. In this case the relevant mirror points are at the base of the altered region or regions. The charged electrons drag ions with them as well as other particles that may be present. Sufficient power, e.g., 10^{15}joules, can be applied so that the altered plasma can be trapped on the field line between mirror points and will oscillate in space for prolonged periods of time. By this embodiment, a plume of altered plasma can be established at selected locations for communication modification or other purposes.

In another embodiment, this invention is used to alter at least one selected region of plasma in the ionosphere to establish a defined layer of plasma having an increased charged particle density. Once this layer is established, and while maintaining the transmission of the main beam of circularly polarized electromagnetic radiation, the main beam is modulated and/or at least one second different, modulated electromagnetic radiation beam is transmitted from at least one separate source at a different frequency which will be absorbed in the plasma layer. The amplitude of the frequency of the main beam and/or the second beam or beams is modulated in resonance with at least one known oscillation mode in the selected region or regions to excite the known oscillation mode to propagate a known frequency wave or waves throughout the ionosphere.

BRIEF DESCRIPTION OF THE DRAWINGS

The actual construction, operation, and apparent advantages of this invention will be better understood by referring to the drawings in which like numerals identify like parts and in which:

FIG. 1 is a simplified schematical view of the earth (not to scale) with a magnetic field (force) line along which the present invention is carried out;

FIG. 2 is one embodiment within the present invention in which a selected region of plasma is raised to a higher altitude;

FIG. 3 is a simplified, idealized representation of a physical phenomenon involved in the present invention; and

FIG. 4 is a schematic view of another embodiment within the present invention.

FIG. 5 is a schematic view of an apparatus embodiment within this invention.

BEST MODES FOR CARRYING OUT THE INVENTION

The earth's magnetic field is somewhat analogous to a dipole bar magnet. As such, the earth's magnetic field contains numerous divergent field or force lines, each line intersecting the earth's surface at points on opposite sides of the Equator. The field lines which intersect the earth's surface near the poles have apexes which lie at the furthest points in the earth's magnetosphere while those closest to the Equator have apexes which reach only the lower portion of the magnetosphere.

At various altitudes above the earth's surface, e.g., in both the ionosphere and the magnetosphere, plasma is naturally present along these field lines. This plasma consists of equal numbers of positively and negatively charged particles (i.e., electrons and ions) which are guided by the field line. It is well established that a charged particle in a magnetic field gyrates about field lines, the center of gyration at any instance being called the "guiding center" of the particle. As the gyrating particle moves along a field line in a uniform field, it will follow a helical path about its guiding center, hence linear motion, and will remain on the field line. Electrons and ions both follow helical paths around a field line but rotate in opposite directions. The frequencies at which the electrons and ions rotate about the field line are called gyromagnetic frequencies or cyclotron frequencies because they are identical with the expression for the angular frequencies of gyration of particles in a cyclotron. The cyclotron frequency of ions in a given magnetic field is less than that of electrons, in inverse proportion to their masses.

If the particles which form the plasma along the earth's field lines continued to move with a constant pitch angle, often designated "alpha", they would soon impact on the earth's surface. Pitch angle alpha is defined as the angle between the direction of the earth's magnetic field and the velocity (V) of the particle. However, in converging force fields, the pitch angle does change in such a way as to allow the particle to turn around and avoid impact. Consider a particle moving along a field line down toward the earth. It moves into a region of increasing magnetic field strength and therefore sine alpha increases. But sine alpha can only increase to 1.0, at which point, the particle turns around and starts moving up along the field line, and alpha decreases. The point at which the particle turns around is called the mirror point, and there alpha equals ninety degrees. This process is repeated at the other end of the field line where the same magnetic field strength value B, namely Bm, exists. The particle again turns around and this is called the "conjugate point" of the original mirror point. The particle is therefore trapped and bounces between the two magnetic mirrors. The particle can continue oscillating in space in this manner for long periods of time. The actual place where a particle will mirror can be calculated from the following:

$$\sin^2 \text{alpha}_o = B_o/B_m \quad (1)$$

wherein:

alpha_o = equatorial pitch angle of particle

B_o = equatorial field strength on a particular field line

B_m = field strength at the mirror point

Recent discoveries have established that there are substantial regions of naturally trapped particles in space which are commonly called "trapped radiation belts". These belts occur at altitudes greater than about 500 km and accordingly lie in the magnetosphere and mostly above the ionosphere.

The ionosphere, while it may overlap some of the trapped-particle belts, is a region in which hydrostatic forces govern its particle distribution in the gravitational field. Particle motion within the ionosphere is governed by both hydrodynamic and electrodynamic forces. While there are few trapped particles in the ionosphere, nevertheless, plasma is present along field lines in the ionosphere. The charged particles which form this plasma move between collisions with other particles along similar helical paths around the field lines and although a particular particle may diffuse downward into the earth's lower atmosphere or lose energy and diverge from its original field line due to collisions with other particles, these charged particles are normally replaced by other available charged particles or by particles that are ionized by collision with said particle. The electron density (N_e) of the plasma will vary with the actual conditions and locations involved. Also, neutral particles, ions, and electrons are present in proximity to the field lines.

The production of enhanced ionization will also alter the distribution of atomic and molecular constituents of the atmosphere, most notably through increased atomic nitrogen concentration. The upper atmosphere is normally rich in atomic oxygen (the dominant atmospheric constituent above 200 km altitude), but atomic nitrogen is normally relatively rare. This can be expected to manifest itself in increased airglow, among other effects.

As known in plasma physics, the characteristics of a plasma can be altered by adding energy to the charged particles or by ionizing or exciting additional particles to increase the density of the plasma. One way to do this is by heating the plasma which can be accomplished in different ways, e.g., ohmic, magnetic compression, shock waves, magnetic pumping, electron cyclotron resonance, and the like.

Since electron cyclotron resonance heating is involved in the present invention, a brief discussion of same is in order. Increasing the energy of electrons in a plasma by invoking electron cyclotron resonance heating, is based on a principle similar to that utilized to accelerate charged particles in a cyclotron. If a plasma is confined by a static axial magnetic field of strength B, the charged particles will gyrate about the lines of force with a frequency given, in hertz, as $f_o = 1.54 \times 10^3 B/A$, where: B = magnetic field strength in gauss, and A = mass number of the ion.

Suppose a time-varying field of this frequency is superimposed on the static field B confining the plasma, by passage of a radiofrequency current through a coil which is concentric with that producing the axial field, then in each half-cycle of their rotation about the field lines, the charged particles acquire energy from the oscillating electric field associated with the radio frequency. For example, if B is 10,000 gauss, the frequency of the field which is in resonance with protons in a plasma is 15.4 megahertz.

As applied to electrons, electron cyclotron resonance heating requires an oscillating field having a definite frequency determined by the strength of the confining field. The radio-frequency radiation produces time-varying fields (electric and magnetic), and the electric field accelerates the charged particle. The energized electrons share their energy with ions and neutrals by undergoing collisions with these particles, thereby effectively raising the temperature of the electrons, ions, and neutrals. The apportionment of energy among these species is determined by collision frequencies. For a more detailed understanding of the physics involved, see "Controlled Thermonuclear Reactions", Glasstone and Lovberg, D. Van Nostrand Company, Inc., Princeton, N.J., 1960 and "The Radiation Belt and Magnetosphere", Hess, Blaisdell Publishing Company, 1968, both of which are incorporated herein by reference.

Referring now to the drawings, the present invention provides a method and apparatus for altering at least one region of plasma which lies along a field line, particularly when it passes through the ionosphere and/or magnetosphere. FIG. **1** is a simplified illustration of the earth **10** and one of its dipole magnetic force or field lines **11**. As will be understood, line **11** may be any one of the numerous naturally existing field lines and the actual geographical locations **13** and **14** of line **11** will be chosen based on a particular operation to be carried out. The actual locations at which field lines intersect the earth's surface is documented and is readily ascertainable by those skilled in the art.

Line **11** passes through region R which lies at an altitude above the earth's surface. A wide range of altitudes are useful given the power that can be employed by the practice of this invention. The electron cyclotron resonance heating effect can be made to act on electrons anywhere above the surface of the earth. These electrons may be already present in the atmosphere, ionosphere, and/or magnetosphere of the earth, or can be artificially generated by a variety of means such as x-ray beams, charged particle beams, lasers, the plasma sheath surrounding an object such as a missile or meteor, and the like. Further, artificial particles, e.g., electrons, ions, etc., can be injected directly into region R from an earth-launched rocket or orbiting satellite carrying, for example, a payload of radioactive beta-decay material; alpha emitters; an electron accelerator; and/or ionized gases such as hydrogen; see U.S. Pat. No. 4,042,196. The altitude can be greater than about 50 km if desired, e.g., can be from about 50 km to about 800 km, and, accordingly may lie in either the ionosphere or the magnetosphere or both. As explained above, plasma will be present along line **11** within region R and is represented by the helical line **12**. Plasma **12** is comprised of charged particles (i.e., electrons and ions) which rotate about opposing helical paths along line **11**.

Antenna **15** is positioned as close as is practical to the location **14** where line **11** intersects the earth's surface. Antenna **15** may be of any known construction for high directionality, for example, a phased array, beam spread angle (θ) type. See "The MST Radar at Poker Flat, Alaska", Radio Science, Vol. 15, No. 2, Mar.-Apr. 1980, pps. 213–223, which is incorporated herein by reference. Antenna **15** is coupled to transmitter **16** which generates a beam of high frequency electromagnetic radiation at a wide range of discrete frequencies, e.g., from about 20 to about 1800 kilohertz (kHz).

Transmitter **16** is powered by power generator means **17** which is preferably comprised of one or more large, commercial electrical generators. Some embodiments of the present invention require large amounts of power, e.g., up to 10^9 to 10^{11} watts, in continuous wave or pulsed power. Generation of the needed power is within the state of the art. Although the electrical generators necessary for the practice of the invention can be powered in any known manner, for example, by nuclear reactors, hydroelectric facilities, hydrocarbon fuels, and the like, this invention, because of its very large power requirement in certain applications, is particularly adapted for use with certain types of fuel sources which naturally occur at strategic geographical locations around the earth. For example, large reserves of hydrocarbons (oil and natural gas) exist in Alaska and Canada. In northern Alaska, particularly the North Slope region, large reserves are currently readily available. Alaska and northern Canada also are ideally located geographically as to magnetic latitudes. Alaska provides easy access to magnetic field lines that are especially suited to the practice of this invention, since many field lines which extend to desirable altitudes for this invention intersect the earth in Alaska. Thus, in Alaska, there is a unique combination of large, accessible fuel sources at desirable field line intersections. Further, a particularly desirable fuel source for the generation of very large amounts of electricity is present in Alaska in abundance, this source being natural gas. The presence of very large amounts of clean-burning natural gas in Alaskan latitudes, particularly on the North Slope, and the availability of magnetohydrodynamic (MHD), gas turbine, fuel cell, electrogasdynamic (EGD) electric generators which operate very efficiently with natural gas provide an ideal power source for the unprecedented power requirements of certain of the applications of this invention. For a more detailed discussion of the various means for generating electricity from hydrocarbon fuels, see "Electrical Aspects of Combustion", Lawton and Weinberg, Clarendon Press, 1969. For example, it is possible to generate the electricity directly at the high frequency needed to drive the antenna system. To do this, typically the velocity of flow of the combustion gases (v), past magnetic field perturbation of dimension d (in the case of MHD), follow the rule:

$$v = df$$

where f is the frequency at which electricity is generated. Thus, if $v = 1.78 \times 10^6$ cm/sec and $d = 1$ cm then electricity would be generated at a frequency of 1.78 mHz.

Put another way, in Alaska, the right type of fuel (natural gas) is naturally present in large amounts and at just the right magnetic latitudes for the most efficient practice of this invention, a truly unique combination of circumstances. Desirable magnetic latitudes for the practice of this invention interest the earth's surface both northerly and southerly of the equator, particularly desirable latitudes being those, both northerly and southerly, which correspond in magnitude with the magnetic latitudes that encompass Alaska.

Referring now to FIG. 2 a first ambodiment is illustrated where a selected region R_1 of plasma **12** is altered by electron cyclotron resonance heating to accelerate the electrons of plasma **12**, which are following helical paths along field line **11**.

To accomplish this result, electromagnetic radiation is transmitted at the outset, essentially parallel to line **11** via antenna **15** as right hand circularly polarized radiation wave **20**. Wave **20** has a frequency which will excite electron cyclotron resonance with plasma **12** at its initial or original altitude. This frequency will vary depending on the electron cyclotron resonance of region R_1 which, in turn, can be determined from available data based on the altitudes of region R_1, the particular field line **11** being used, the strength of the earth's magnetic field, etc. Frequencies of from about 20 to about 7200 kHz, preferably from about 20 to about 1800 kHz can be employed. Also, for any given application, there will be a threshhold (minimum power level) which is needed to produce the desired result. The minimum power level is a function of the level of plasma production and movement required, taking into consideration any loss processes that may be dominant in a particular plasma or propagation path.

As electron cyclotron resonance is established in plasma **12**, energy is transferred from the electromagnetic radiation **20** into plasma **12** to heat and accelerate the electrons therein and, subsequently, ions and neutral particles. As this process continues, neutral particles which are present within R_1 are ionized and absorbed into plasma **12** and this increases the electron and ion densities of plasma **12**. As the electron energy is raised to values of about 1 kilo electron volt (kev), the generated mirror force (explained below) will direct the excited plasma **12** upward along line **11** to form a plume R_2 at an altitude higher than that of R_1.

Plasma acceleration results from the force on an electron produced by a nonuniform static magnetic field ($\bar{B}$). The force, called the mirror force, is given by

$$F = -\mu \nabla B \qquad (2)$$

where μ is the electron magnetic moment and $\nabla \bar{B}$ is the gradient of the magnetic field, μ being further defined as:

$$W_\perp / B = mV_\perp^2 / 2B$$

where $W_\perp$ is the kinetic energy in the direction perpendicular to that of the magnetic field lines and B is the magnetic field strength at the line of force on which the guiding center of the particle is located. The force as represented by equation (2) is the force which is responsible for a particle obeying equation (1).

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Since the magnetic field is divergent in region R_1, it can be shown that the plasma will move upwardly from the heating region as shown in FIG. 1 and further it can be shown that

$$\tfrac{1}{2}M_e V_{e\perp}^2(x) \approx \tfrac{1}{2}M_e V_{e\perp}^2(Y) + \tfrac{1}{2}M_i V_{i\parallel}^2(Y) \qquad (3)$$

where the left hand side is the initial electron transverse kinetic energy; the first term on the right is the transverse electron kinetic energy at some point (Y) in the expanded field region, while the final term is the ion kinetic energy parallel to B at point (Y). This last term is what constitutes the desired ion flow. It is produced by an electrostatic field set up by electrons which are accelerated according to Equation (2) in the divergent field region and pulls ions along with them. Equation (3) ignores electron kinetic energy parallel to B because $V_{e\parallel} \approx V_{i\parallel}$, so the bulk of parallel kinetic energy resides in the ions because of their greater masses. For example, if an electromagnetic energy flux of from about 1 to about 10 watts per square centimeter is applied to region R, whose altitude is 115 km, a plasma having a density (N_e) of 10^{12} per cubic centimeter will be generated and moved upward to region R_2 which has an altitude of about 1000 km. The movement of electrons in the plasma is due to the mirror force while the ions are moved by ambipolar diffusion (which results from the electrostatic field). This effectively "lifts" a layer of plasma **12** from the ionosphere and/or magnetosphere to a higher elevation R_2. The total energy required to create a plasma with a base area of 3 square kilometers and a height of 1000 km is about 3×10^{13} joules.

FIG. **3** is an idealized representation of movement of plasma **12** upon excitation by electron cyclotron resonance within the earth's divergent force field. Electrons (e) are accelerated to velocities required to generate the necessary mirror force to cause their upward movement. At the same time neutral particles (n) which are present along line **11** in region R_1 are ionized and become part of plasma **12**. As electrons (e) move upward along line **11**, they drag ions (i) and neutrals (n) with them but at an angle θ of about 13 degrees to field line **11**. Also, any particulates that may be present in region R_1, will be swept upwardly with the plasma. As the charged particles of plasma **12** move upward, other particles such as neutrals within or below R_1, move in to replace the upwardly moving particles. These neutrals, under some conditions, can drag with them charged particles.

For example, as a plasma moves upward, other particles at the same altitude as the plasma move horizontally into the region to replace the rising plasma and to form new plasma. The kinetic energy developed by said other particles as they move horizontally is, for example, on the same order of magnitude as the total zonal kinetic energy of stratospheric winds known to exist.

Referring again to FIG. **2**, plasma **12** in region R_1 is moved upward along field line **11**. The plasma **12** will then form a plume (cross-hatched area in FIG. **2**) which will be relatively stable for prolonged periods of time. The exact period of time will vary widely and be determined by gravitational forces and a combination of radiative and diffusive loss terms. In the previous detailed example, the calculations were based on forming a plume by producing 0^+energies of 2 ev/particle. About 10 ev per particle would be required to expand plasma **12** to apex point C (FIG. **1**). There at least some of the particles of plasma **12** will be trapped and will oscillate between mirror points along field line **11**. This

oscillation will then allow additional heating of the trapped plasma **12** by stochastic heating which is associated with trapped and oscillating particles. See "A New Mechanism for Accelerating Electrons in the Outer Ionosphere" by R. A. Helliwell and T. F. Bell, Journal of Geophysical Research, Vol. 65, No. 6, June, 1960. This is preferably carried out at an altitude of at least 500 km.

The plasma of the typical example might be employed to modify or disrupt microwave transmissions of satellites. If less than total black-out of transmission is desired (e.g., scrambling by phase shifting digital signals), the density of the plasma (N_e) need only be at least about 10^6 per cubic centimeter for a plasma orginating at an altitude of from about 250 to about 400 km and accordingly less energy (i.e., electromagnetic radiation), e.g., 10^8 joules need be provided. Likewise, if the density $N_e$is on the order of 10^8, a properly positioned plume will provide a reflecting surface for VHF waves and can be used to enhance, interfere with, or otherwise modify communication transmissions. It can be seen from the foregoing that by appropriate application of various aspects of this invention at strategic locations and with adequate power sources, a means and method is provided to cause interference with or even total disruption of communications over a very large portion of the earth. This invention could be employed to disrupt not only land based communications, both civilian and military, but also airborne communications and sea communications (both surface and subsurface). This would have significant military implications, particularly as a barrier to or confusing factor for hostile missiles or airplanes. The belt or belts of enhanced ionization produced by the method and apparatus of this invention, particularly if set up over Northern Alaska and Canada, could be employed as an early warning device, as well as a communications disruption medium. Further, the simple ability to produce such a situation in a practical time period can by itself be a deterring force to hostile action. The ideal combination of suitable field lines intersecting the earth's surface at the point where substantial fuel sources are available for generation of very large quantitities of electromagnetic power, such as the North Slope of Alaska, provides the wherewithal to accomplish the foregoing in a practical time period, e.g., strategic requirements could necessitate achieving the desired altered regions in time periods of two minutes or less and this is achievable with this invention, especially when the combination of natural gas and magnetohydrodynamic, gas turbine, fuel cell and/or EGD electric generators are employed at the point where the useful field lines intersect the earth's surface. One feature of this invention which satisfies a basic requirement of a weapon system, i.e., continuous checking of operability, is that small amounts of power can be generated for operability checking purposes. Further, in the exploitation of this invention, since the main electromagnetic beam which generates the enhanced ionized belt of this invention can be modulated itself and/or one or more additional electromagnetic radiation waves can be impinged on the ionized region formed by this invention as will be described in greater detail herein after with respect to FIG. **4**, a substantial amount of randomly modulated signals of very large power magnitude can be generated in a highly nonlinear mode. This can cause confusion of or interference with or even complete disruption of guidance systems employed by

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even the most sophisticated of airplanes and missiles. The ability to employ and transmit over very wide areas of the earth a plurality of electromagnetic waves of varying frequencies and to change same at will in a random manner, provides a unique ability to interfere with all modes of communications, land, sea, and/or air, at the same time. Because of the unique juxtaposition of usable fuel source at the point where desirable field lines intersect the earth's surface, such wide ranging and complete communication interference can be achieved in a resonably short period of time. Because of the mirroring phenomenon discussed hereinabove, it can also be prolonged for substantial time periods so that it would not be a mere transient effect that could simply be waited out by an opposing force. Thus, this invention provides the ability to put unprecedented amounts of power in the earth's atmosphere at strategic locations and to maintain the power injection level, particularly if random pulsing is employed, in a manner far more precise and better controlled than heretofore accomplished by the prior art, particularly by the detonation of nuclear devices of various yeilds at various altitudes. Where the prior art approaches yielded merely transitory effects, the unique combination of fuel and desirable field lines at the point where the fuel occurs allows the establishment of, compared to prior art approaches, precisely controlled and long-lasting effects which cannot, practically speaking, simply be waited out. Further, by knowing the frequencies of the various electromagnetic beams employed in the practice of this invention, it is possible not only to interfere with third party communications but to take advantage of one or more such beams to carry out a communications network even though the rest of the world's communications are disrupted. Put another way, what is used to disrupt another's communications can be employed by one knowledgeable of this invention as a communications network at the same time. In addition, once one's own communication network is established, the far-reaching extent of the effects of this invention could be employed to pick up communication signals of other for intelligence purposes. Thus, it can be seen that the disrupting effects achievable by this invention can be employed to benefit by the party who is practicing this invention since knowledge of the various electromagnetic waves being employed and how they will vary in frequency and magnitude can be used to an advantage for positive communication and eavesdropping purposes at the same time. However, this invention is not limited to locations where the fuel source naturally exists or where desirable field lines naturally intersect the earth's surface. For example, fuel, particularly hydrocarbon fuel, can be transported by pipeline and the like to the location where the invention is to be practiced.

FIG. 4 illustrates another embodiment wherein a selected region of plasma R_3 which lies within the earth's ionosphere is altered to increase the density thereof whereby a relatively stable layer 30 of relatively dense plasma is maintained within region R_3. Electromagnetic radiation is transmitted at the outset essentially parallel to field line 11 via antenna 15 as a right hand circularly polarized wave and at a frequency (e.g., 1.78 megahertz when the magnetic field at the desired altitude is 0.66 gauss) capable of exciting electron cyclotron resonance in plasma 12 at the particular altitude of plasma 12. This causes heating of the particles (electrons, ions, neutrals, and particulates) and ionization of the uncharged particles adjacent line 11, all of which are absorbed into plasma 12 to increase the density thereof. The power transmitted, e.g., 2×10^6 watts for up to 2 minutes heating time, is less than that required to generate the mirror force F required to move plasma 12 upward as in the previous embodiment.

While continuing to transmit electromagnetic radiation 20 from antenna 15, a second electromagnetic radiation beam 31, which is at a defined frequency different from the radiation from antenna 15, is transmitted from one or more second sources via antenna 32 into layer 30 and is absorbed into a portion of layer 30 (cross-hatched area in FIG. 4). The electromagnetic radiation wave from antenna 32 is amplitude modulated to match a known mode of oscillation f_3 in layer 30. This creates a resonance in layer 30 which excites a new plasma wave 33 which also has a frequency of f_3 and which then propogates through the ionosphere. Wave 33 can be used to improve or disrupt communications or both depending on what is desired in a particular application. Of course, more than one new wave 33 can be generated and the various new waves can be modulated at will and in a highly nonlinear fashion.

FIG. 5 shows apparatus useful in this invention, particularly when those applications of this invention are employed which require extremely large amounts of power. In FIG. 5 there is shown the earth's surface 40 with a well 41 extending downwardly thereinto until it penetrates hydrocarbon producing reservoir 42. Hydrocarbon reservoir 42 produces natural gas alone or in combination with crude oil. Hydrocarbons are produced from reservoir 42 through well 41 and wellhead 43 to a treating system 44 by way of pipe 45. In treater 44, desirable liquids such as crude oil and gas condensates are separated and recovered by way of pipe 46 while undesirable gases and liquids such as water, H_2S, and the like are separated by way of pipe 47. Desirable gases such as carbon dioxide are separated by way of pipe 48, and the remaining natural gas stream is removed from treater 44 by way of pipe 49 for storage in conventional tankage means (not shown) for future use and/or use in an electrical generator such as a magnetohydrodynamic, gas turbine, fuel cell or EGD generator 50. Any desired number and combination of different types of electric generators can be employed in the practice of this invention. The natural gas is burned in generator 50 to produce substantial quantities of electricity which is then stored and/or passed by way of wire 51 to a transmitter 52 which generates the electromagnetic radiation to be used in the method of this invention. The electromagnetic radiation is then passed by way of wire 53 to antenna 54 which is located at or near the end of field line 11. Antenna 54 sends circularly polarized radiation wave 20 upwards along field line 11 to carry out the various methods of this invention as described hereinabove.

Of course, the fuel source need not be used in its naturally-occurring state but could first be converted to another second energy source form such as hydrogen, hydrazine and the like, and electricity then generated from said second energy source form.

It can be seen from the foregoing that when desirable field line 11 intersects earth's surface 40 at or near a large naturally-occurring hydrocarbon source 42, exceedingly large amounts of power can be very efficiently produced and transmitted in the direction of field lines. This is particularly so when the fuel source is natural gas and magnetohydrodynamic generators are employed. Further, this can all be accomplished in a

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relatively small physical area when there is the unique coincidence of fuel source **42** and desirable field line **11**. Of course, only one set of equipment is shown in FIG. **5** for sake of simplicity. For a large hydrocarbon reservoir **42**, a plurality of wells **41** can be employed to feed one or more storage means and/or treaters and as large a number of generators **55** as needed to power one or more transmitters **52** and one or more antennas **54**. Since all of the apparatus **44** through **54** can be employed and used essentially at the sight where naturally-occurring fuel source **42** is located, all the necessary electromagnetic radiation **20** is generated essentially at the same location as fuel source **42**. This provides for a maximum amount of usable electromagnetic radiation **20** since there are no significant storage or transportation losses to be incurred. In other words, the apparatus is brought to the sight of the fuel source where desirable field line **11** intersects the earth's surface **40** on or near the geographical location of fuel source **42**, fuel source **42** being at a desirable magnetic latitude for the practice of this invention, for example, Alaska.

The generation of electricity by motion of a conducting fluid through a magnetic field, i.e., magnetohydrodynamics (MHD), provides a method of electric power generation without moving mechanical parts and when the conducting fluid is a plasma formed by combustion of a fuel such as natural gas, an idealized combination of apparatus is realized since the very clean-burning natural gas forms the conducting plasma in an efficient manner and the thus formed plasma, when passed through a magnetic field, generates electricity in a very efficient manner. Thus, the use of fuel source **42** to generate a plasma by combustion thereof for the generation of electricity essentially at the site of occurrence of the fuel source is unique and ideal when high power levels are required and desirable field lines **11** intersect the earth's surface **40** at or near the site of fuel source **42**. A particular advantage for MHD generators is that they can be made to generate large amounts of power with a small volume, light weight device. For example, a 1000 megawatt MHD generator can be construed using superconducting magnets to weigh roughly 42,000 pounds and can be readily air lifted.

This invention has a phenomenal variety of possible ramifications and potential future developments. As alluded to earlier, missile or aircraft destruction, deflection, or confusion could result, particularly when relativistic particles are employed. Also, large regions of the atmosphere could be lifted to an unexpectedly high altitude so that missiles encounter unexpected and unplanned drag forces with resultant destruction or deflection of same. Weather modification is possible by, for example, altering upper atmosphere wind patterns or altering solar absorption patterns by constructing one or more plumes of atmospheric particles which will act as a lens or focusing device. Also as alluded to earlier, molecular modifications of the atmosphere can take place so that positive environmental effects can be achieved. Besides actually changing the molecular composition of an atmospheric region, a particular molecule or molecules can be chosen for increased presence. For example, ozone, nitrogen, etc. concentrations in the atmosphere could be artificially increased. Similarly, environmental enhancement could be achieved by causing the breakup of various chemical entities such as carbon dioxide, carbon monoxide, nitrous oxides, and the like. Transportation of entities can also be realized when advantage is taken of the drag effects caused by regions of the atmosphere moving up along diverging field lines. Small micron sized particles can be then transported, and, under certain circumstances and with the availability of sufficient energy, larger particles or objects could be similarly affected. Particles with desired characteristics such as tackiness, reflectivity, absorptivity, etc., can be transported for specific purposes or effects. For example, a plume of tacky particles could be established to increase the drag on a missile or satellite passing therethrough. Even plumes of plasma having substantially less charged particle density than described above will produce drag effects on missiles which will affect a lightweight (dummy) missile in a manner substantially different than a heavy (live) missile and this affect can be used to distinguish between the two types of missiles. A moving plume could also serve as a means for supplying a space station or for focusing vast amount of sunlight on selected portions of the earth. Surveys of global scope could also be realized because the earth's natural magnetic field could be significantly altered in a controlled manner by plasma beta effects resulting in, for example, improved magnetotelluric surveys. Electromagnetic pulse defenses are also possible. The earth's magnetic field could be decreased or disrupted at appropriate altitudes to modify or eliminate the magnetic field in high Compton electron generation (e.g., from high altitude nuclear bursts) regions. High intensity, well controlled electrical fields can be provided in selected locations for various purposes. For example, the plasma sheath surrounding a missile or satellite could be used as a trigger for activating such a high intensity field to destroy the missile or satellite. Further, irregularities can be created in the ionosphere which will interfere with the normal operation of various types of radar, e.g., synthetic aperture radar. The present invention can also be used to create artificial belts of trapped particles which in turn can be studied to determine the stability of such parties. Still further, plumes in accordance with the present invention can be formed to simulate and/or perform the same functions as performed by the detonation of a "heave" type nuclear device without actually having to detonate such a device. Thus it can be seen that the ramifications are numerous, far-reaching, and exceedingly varied in usefulness.

I claim:

1. A method for altering at least one region normally existing above the earth's surface with electromagnetic radiation using naturally-occurring and diverging magnetic field lines of the earth comprising transmitting first electromagnetic radiation at a frequency between 20 and 7200 kHz from the earth's surface, said transmitting being conducted essentially at the outset of transmission substantially parallel to and along at least one of said field lines, adjusting the frequency of said first radiation to a value which will excite electron cyclotron resonance at an initial elevation at least 50 km above the earth's surface, whereby in the region in which said electron cyclotron resonance takes place heating, further ionization, and movement of both charged and neutral particles is effected, said cyclotron resonance excitation of said region is continued until the electron concentration of said region reaches a value of at least 10^6 per cubic centimeter and has an ion energy of at least 2 ev.

2. The method of claim **1** including the step of providing artificial particles in said at least one region which are excited by said electron cyclotron resonance.

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3. The method of claim **2** wherein said artificial particles are provided by injecting same into said at least one region from an orbiting satellite.

4. The method of claim **1** wherein said threshold excitation of electron cyclotron resonance is about 1 watt per cubic centimeter and is sufficient to cause movement of a plasma region along said diverging magnetic field lines to an altitude higher than the altitude at which said excitation was initiated.

5. The method of claim **4** wherein said rising plasma region pulls with it a substantial portion of neutral particles of the atmosphere which exist in or near said plasma region.

6. The method of claim **1** wherein there is provided at least one separate source of second electromagnetic radiation, said second radiation having at least one frequency different from said first radiation, impinging said at least one second radiation on said region while said region is undergoing electron cyclotron resonance excitation caused by said first radiation.

7. The method of claim **6** wherein said second radiation has a frequency which is absorbed by said region.

8. The method of claim **6** wherein said region is plasma in the ionosphere and said second radiation excites plasma waves within said ionosphere.

9. The method of claim **8** wherein said electron concentration reaches a value of at least 10^{12} per cubic centimeter.

10. The method of claim **8** wherein said excitation of electron cyclotron resonance is initially carried out within the ionosphere and is continued for a time sufficient to allow said region to rise above said ionosphere.

11. The method of claim **1** wherein said excitation of electron cyclotron resonance is carried out above about 500 kilometers and for a time of from 0.1 to 1200 seconds such that multiple heating of said plasma region is achieved by means of stochastic heating in the magnetosphere.

12. The method of claim **1** wherein said first electromagnetic radiation is right hand circularly polarized in the northern hemisphere and left hand circularly polarized in the southern hemisphere.

13. The method of claim **1** wherein said electromagnetic radiation is generated at the site of a naturally-occurring hydrocarbon fuel source, said fuel source being located in at least one of northerly or southerly magnetic latitudes.

14. The method of claim **13** wherein said fuel source is natural gas and electricity for generating said electromagnetic radiation is obtained by burning said natural gas in at least one of magnetohydrodynamic, gas turbine, fuel cell, and EGD electric generators located at the site where said natural gas naturally occurs in the earth.

15. The method of claim **14** wherein said site of natural gas is within the magnetic latitudes that encompass Alaska.

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APPENDIX 12

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PRAVDA(RU)
online since January 27th.1999

USA and Russia supposedly develop secret meteorological weapons

30.09.2005 ◘ **Source:** ◘ **URL:** http://english.pravda.ru/science/tech/8992-hurricanes-0

American meteorologist Scott Stevens has recently brought accusations against Russia

Mr. Stevens claims that Russian military specialists were behind the fury of Hurricane Katrina that devastated New Orleans. According to him, Russia has built secret equipment for causing a detrimental impact on the weather way back in the Soviet era.

U.S. media quickly spread the news around. Both Russia and the U.S. were long rumored to have been involved in the development of meteorological weapon. But those rumors seemed too wild to searching a grain of truth hidden underneath. In the meantime, some Russian politicians say the experiments have been conducted and still conducted on either side of the ocean. Following death and destruction caused by Katrina, The Americans promptly unearthed the controversial interview by Vladimir Zhirinovsky in which he threatened to unleash floods all over the United States when "our scientists slightly change the earth's gravitational field." Nobody got scared watching the drunken boss of the Liberal Democratic Party promise doom's day for the United States. But once Katrina struck and the southern part of the U.S. got drowned, the improbable rumors about Russia's meteorological weapon came to light again.

American meteorologists are not the only ones who blame the neighbors for using the "hurricane gun." Unconfirmed and patchy reports on questionable experiments with weather conducted by the U.S. and Soviet Union stirred up a number of political scandals in many countries of the world. Following a large-scale flooding in Europe in 2002, some European politicians put the blame on the "U.S. military" for disrupting EU economy. In 2002, Committee for Defense of the Russian Duma raised the issue about a detrimental impact on climate caused by experiments involving disturbance of the earth's ionosphere and magnetosphere. The deputies focused their attention on HAARP system that is still under construction in Alaska.

There is a special facility located at a military installation some 400 km north of Anchorage. A huge area of tundra features thousands of 25-m antennas pointing to the sky. The facility is called High Frequency Active Auroral Research Program (HAARP). U.S. Marines patrol the vicinity of the base. No commercial or military aircraft are allowed to fly over the base. Air-defense systems Patriot were installed around the base following the 9/11 terrorist attacks.

U.S. Navy and U.S. Air Force combined efforts building the facility. Open information sources indicate that the facility is used for causing active influence on the earth's ionosphere and magnetosphere. The results could be fantastic, according to scientific journals. Scientific journals claim that HAARP is capable of causing artificial aurora borealis, it can also jam radar stations of early ballistic missile detection systems, communicate with submarines in the ocean and even detect secret underground complexes of the enemy. Radio-frequency emission is capable of piercing through the ground and examine hideaways and tunnels, it can burn out electronics and destroy space satellites. The equipment can also impact the atmosphere and thus cause changes in weather. HAARP is allegedly used for causing natural disasters similar to Huricanes Katrina and Rita.

Three years ago the Duma deputies held a heated discussion of issues related to HAARP. They even drew up an appeal to the President Putin and the UN. They demanded to set up an international commission for the investigation of the experiments conducted in Alaska.

Speaking to *Nezavisimaya Gazeta*, specialist for active influence on the atmosphere of the Federal Service of Hydrometeorology and Environmental Monitoring Valery Stasenko said HAARP is a "very serious issue." "It is not for nothing that the term 'space weather' has become quite popular lately.

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The term stands for interrelation between the solar activity, magnetosphere and ionosphere perturbations and developments in the atmosphere. Perturbations in the magnetosphere and ionosphere can really impact climate. Using powerful equipment for deliberately bringing about perturbations, one can impact weather too, even on a global scale. I believe the deputies were right in finally raising the issue regarding the experiments in the U.S.," said Mr. Stasenko.

Russian politicians are head over heels debating plans of U.S. imperialists and their bloodthirsty military, man-made disasters and floods. They are probably totally unaware that Russia has long build it own facility similar to HAARP. The facility Sura is as powerful as HAARP. It is located in Russia's central area, in a remote and desolate place some 150 km from the city of Nizhny Novgorod. One of the leading scientific research institutions of the USSR, Research Institute of Radiophysical Studies, owns the facility.

"There are only three facilities like this in the world, one is in Alaska, the very HAARP, one in Norway, and one in Russia," said Nikolai Snegirev, director of the above institute. The facility was commissioned in 1981. "Using this unique facility, researchers achieved extremely interesting results regarding the ionosphere behavior. They discovered the effect of generation of low-frequency emission at the modulation of ionosphere current. At the beginning, Soviet Defense Department mostly footed the bill for similar research projects. Alas, no research like that has been conducted at the facility since the collapse of the Soviet Union. These days we are involved in the international projects for research of the ionosphere," said Mr. Snegirev.

Sura looks quite seasoned and a little bit rusty. Against all odds, it still works. There are straight lines of 20-m antennas standing in an area of 9 hectares. A giant emitter the size of a country hut sits in the center of the field, the emitter is used for studying acoustic developments in the atmosphere.

Researchers at the Sura can not yet conjure hurricanes similar to Katrina and Rita. At least they say they can not. However, they conduct research (on a smaller scale than in the U.S.) of interrelation between the natural disasters and perturbations in the ionosphere and magnetosphere.

"It is possible to impact weather. However, neither Russians nor Americans are capable at the moment of creating something like Hurricanes Katrina or Rita. The capacity of the facilities is too low. The Americans are going to switch HAARP into its design capacity. Still, it will not be enough for effectively causing natural disasters," said Yuri Tokarev, head of department of solar and terrestrial relations of the Research Institute of Radiophysical Studies.

Technologies of the secret research institutes that used too be classified and inaccessible become available to non-military researchers. One of the devices was recently tested thanks to support of the Russian Academy of Natural Sciences.

"We produced lots of interesting results during the first test of the ionic generator," said Academician Mikhail Shahramanyan. "A stream of oxygen ions was going up and could either result in a local rupture of the clouds or bring out overcast sky, depending on a work mode of the device. We managed to form cumulonimbus overcast sky over Erevan in April 2004. We used two GIONK type devices when the sky was clear. According to protocols verified by independent observers, between April 15 to April 16 in Erevan precipitation totaled to 25mm-27mm," said Academician Shahramanyan.

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APPENDIX 13

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Weather as a Force Multiplier: Owning the Weather in 2025

A Research Paper
Presented To

Air Force *2025*

by

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August 1996

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Disclaimer

2025 is a study designed to comply with a directive from the chief of staff of the Air Force to examine the concepts, capabilities, and technologies the United States will require to remain the dominant air and space force in the future. Presented on 17 June 1996, this report was produced in the Department of Defense school environment of academic freedom and in the interest of advancing concepts related to national defense. The views expressed in this report are those of the authors and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States government.

This report contains fictional representations of future situations/scenarios. Any similarities to real people or events, other than those specifically cited, are unintentional and are for purposes of illustration only.

This publication has been reviewed by security and policy review authorities, is unclassified, and is cleared for public release.

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Table 1

Operational Capabilities Matrix

DEGRADE ENEMY FORCES

Precipitation Enhancement

- Flood Lines of Communication
- Reduce PGM/Recce Effectiveness
- Decrease Comfort Level/Morale

Storm Enhancement

- Deny Operations

Precipitation Denial

- Deny Fresh Water
- Induce Drought

Space Weather

- Disrupt Communications/Radar
- Disable/Destroy Space Assets

Fog and Cloud Removal

- Deny Concealment
- Increase Vulnerability to PGM/Recce

Detect Hostile Weather Activities

ENHANCE FRIENDLY FORCES

Precipitation Avoidance

- Maintain/Improve LOC
- Maintain Visibility
- Maintain Comfort Level/Morale

Storm Modification

- Choose Battlespace Environment

Space Weather

- Improve Communication Reliability
- Intercept Enemy Transmissions
- Revitalize Space Assets

Fog and Cloud Generation

- Increase Concealment

Fog and Cloud Removal

- Maintain Airfield Operations
- Enhance PGM Effectiveness

Defend against Enemy Capabilities

Current technologies that will mature over the next 30 years will offer anyone who has the necessary resources the ability to modify weather patterns and their corresponding effects, at least on the local scale. Current demographic, economic, and environmental trends will create global stresses that provide the impetus necessary for many countries or groups to turn this weather-modification ability into a capability.

In the United States, weather-modification will likely become a part of national security policy with both domestic and international applications. Our government will pursue such a policy, depending on its interests, at various levels. These levels could include unilateral actions, participation in a security framework such as NATO, membership in an international organization such as the UN, or participation in a coalition. Assuming that in 2025 our national security strategy includes weather-modification, its use in our national military strategy will naturally follow. Besides the significant benefits an operational capability would provide, another motivation to pursue weather-modification is to deter and counter potential adversaries.

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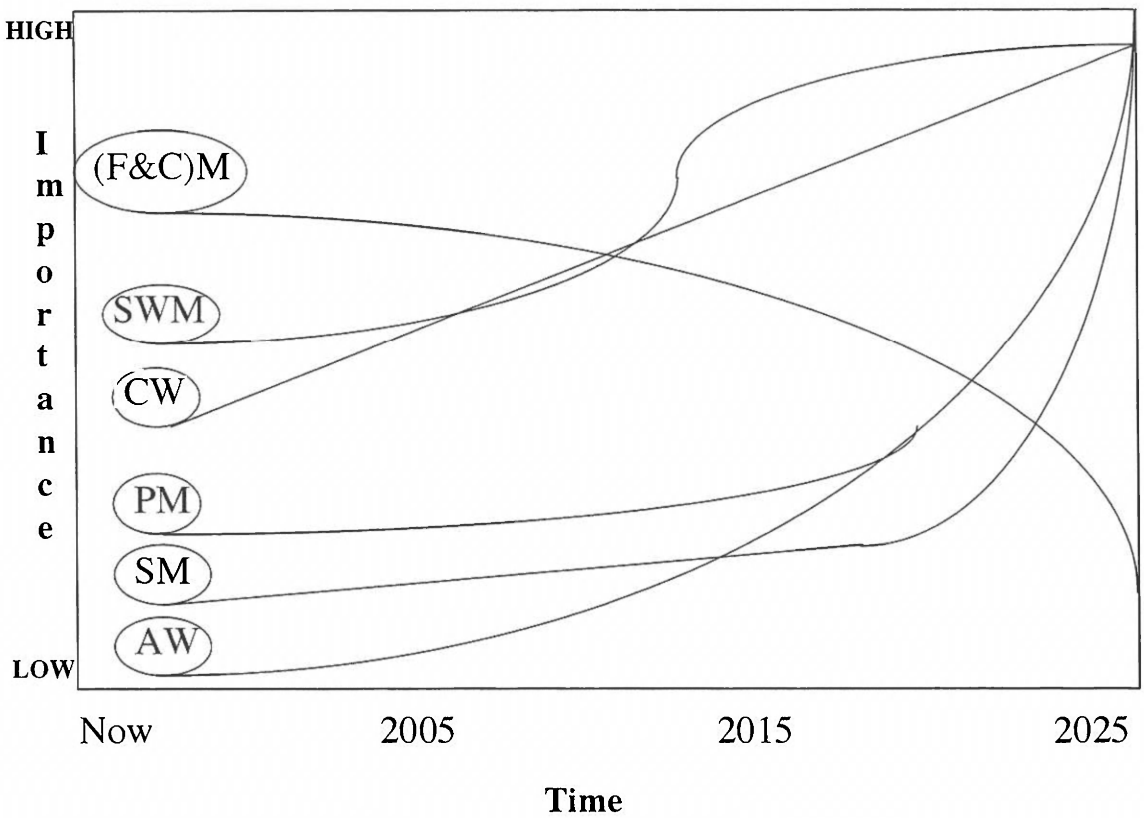

Legend

PM	Precipitation Modification	**(F&C)M**	Fog and Cloud Modification
SM	Storm Modification	**CW**	Counter Weather
SWM	Space Weather-modification	**AW**	Artificial Weather

Figure 5-1. A Core Competency Road Map to Weather Modification in 2025.

Even today's most technologically advanced militaries would usually prefer to fight in clear weather and blue skies. But as war-fighting technologies proliferate, the side with the technological advantage will prefer to fight in weather that gives them an edge. The US Army has already alluded to this approach in their concept of "owning the weather."[1] Accordingly, storm modification will become more valuable over time. The importance of precipitation modification is also likely to increase as usable water sources become more scarce in volatile parts of the world.

As more countries pursue, develop, and exploit increasing types and degrees of weather-modification technologies, we must be able to detect their efforts and counter their activities when necessary. As depicted, the technologies and capabilities associated with such a counter weather role will become increasingly important.

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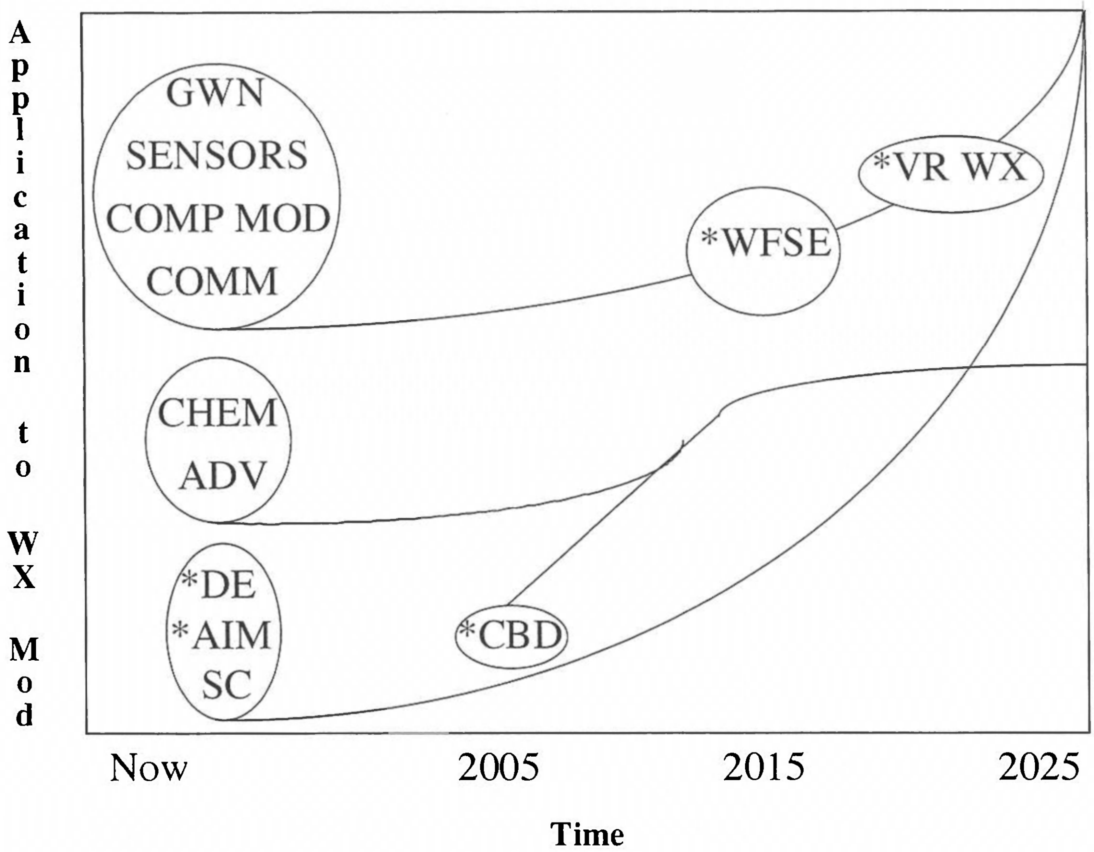

Legend

ADV	Aerospace Delivery Vehicles	**DE**	Directed Energy
AIM	Artificial Ionospheric Mirrors	**GWN**	Global Weather Network
CHEM	Chemicals	**SC**	Smart Clouds (nanotechnology)
CBD	Carbon Black Dust	**SENSORS**	Sensors
COMM	Communications	**VR WX**	Virtual Weather
COMP MOD	Computer Modeling	**WFSE**	Weather Force Support Element

* Technologies to be developed by DOD

Figure 5-2. A Systems Development Road Map to Weather Modification in 2025.

Conclusions

The world's finite resources and continued needs will drive the desire to protect people and property and more efficiently use our crop lands, forests, and range lands. The ability to modify the weather may be desirable both for economic and defense reasons. The global weather system has been described as a series of spheres or bubbles. Pushing down on one causes another to pop up.[2] We need to know when another power "pushes" on a sphere in their region, and how that will affect either our own territory or areas of economic and political interest to the US.

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APPENDIX 14

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United States Patent [19]

Chang et al.

[11] **Patent Number: 5,003,186**

[45] **Date of Patent: Mar. 26, 1991**

[54] **STRATOSPHERIC WELSBACH SEEDING FOR REDUCTION OF GLOBAL WARMING**

[75] Inventors: **David B. Chang**, Tustin; **I-Fu Shih**, Los Alamitos, both of Calif.

[73] Assignee: **Hughes Aircraft Company**, Los Angeles, Calif.

[21] Appl. No.: **513,145**

[22] Filed: **Apr. 23, 1990**

[51] **Int. Cl.**^{5} **G21K 1/00**

[52] **U.S. Cl.** .... **250/505.1**; 250/504 R; 250/503.1; 244/158 R

[58] **Field of Search** .... 250/505.1, 504 R, 503.1, 250/493.1; 244/136, 158 R

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,222,675 12/1965 Schwartz 244/158

4,755,673 7/1988 Pollack et al. 250/330

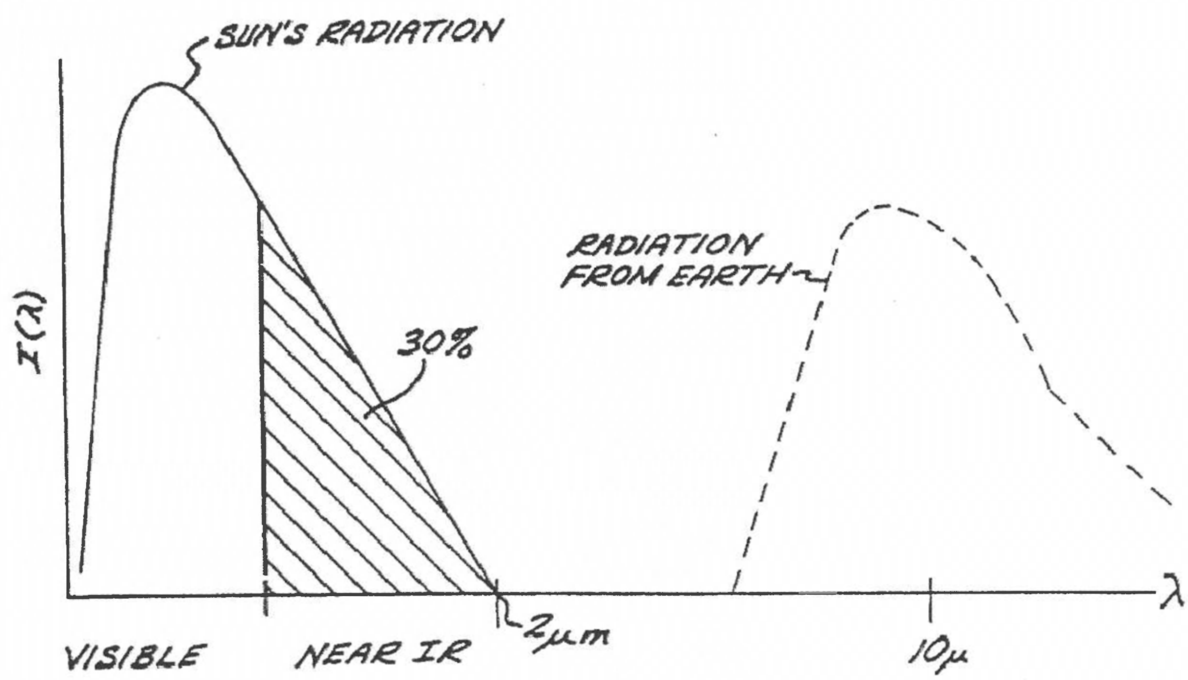
Primary Examiner—Jack I. Berman

Attorney, Agent, or Firm—Michael W. Sales; Wanda Denson-Low

[57] **ABSTRACT**

A method is described for reducing atmospheric or global warming resulting from the presence of heat-trapping gases in the atmosphere, i.e., from the greenhouse effect. Such gases are relatively transparent to sunshine, but absorb strongly the long-wavelength infrared radiation released by the earth. The method incudes the step of seeding the layer of heat-trapping gases in the atmosphere with particles of materials characterized by wavelength-dependent emissivity. Such materials include Welsbach materials and the oxides of metals which have high emissivity (and thus low reflectivities) in the visible and 8–12 micron infrared wavelength regions.

18 Claims, 2 Drawing Sheets



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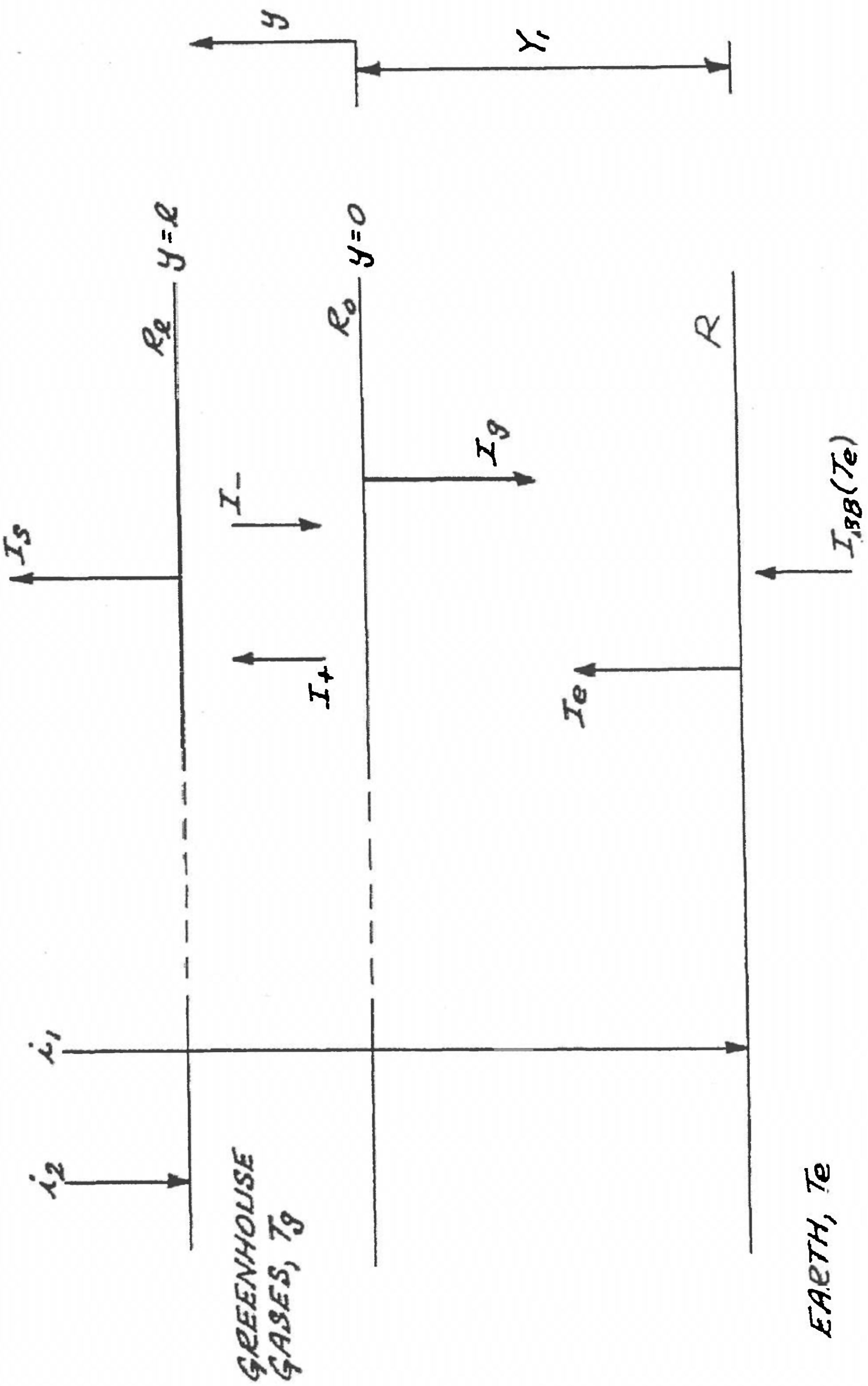

y
Y_1
$y=\ell$
$y=0$
R_ℓ
R_0
R
I_s
I_-
I_+
I_g
$I_{BB}(T_e)$
I_e
i_1
i_2
GREENHOUSE GASES, T_g
EARTH, T_e

FIG. 1

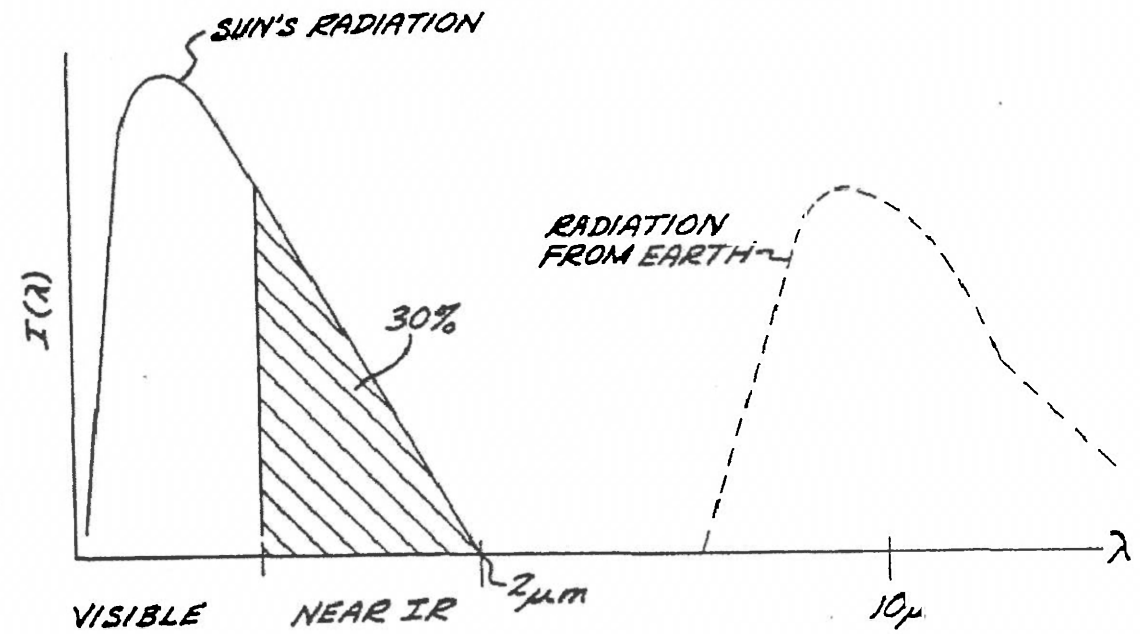
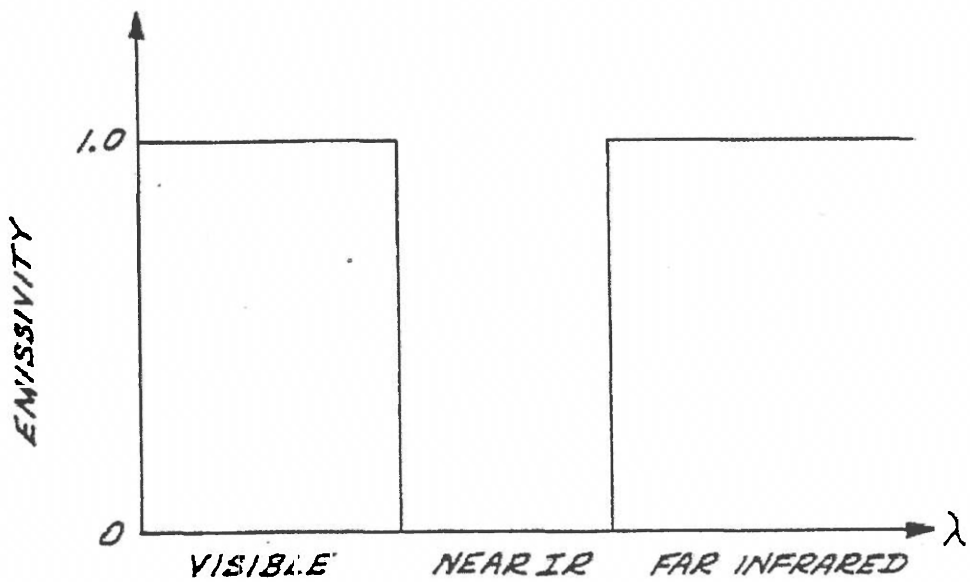

SUN'S RADIATION
RADIATION FROM EARTH
30%
I(λ)
λ
2μm
10μ
VISIBLE
NEAR IR

FIG. 2

FIG. 3


1.0
EMISSIVITY
0
λ
VISIBLE
NEAR IR
FAR INFRARED

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STRATOSPHERIC WELSBACH SEEDING FOR REDUCTION OF GLOBAL WARMING

BACKGROUND OF THE INVENTION

This invention relates to a method for the reduction of global warming resulting from the greenhouse effect, and in particular to a method which involves the seeding of the earth's stratosphere with Welsbach-like materials.

Global warming has been a great concern of many environmental scientists. Scientists believe that the greenhouse effect is responsible for global warming. Greatly increased amounts of heat-trapping gases have been generated since the Industrial Revolution. These gases, such as CO_2, CFC, and methane, accumulate in the atmosphere and allow sunlight to stream in freely but block heat from escaping (greenhouse effect). These gases are relatively transparent to sunshine but absorb strongly the long-wavelength infrared radiation released by the earth.

Most current approaches to reduce global warming are to restrict the release of various greenhouse gases, such as CO_2, CFC, and methane. These imply the need to establish new regulations and the need to monitor various gases and to enforce the regulations.

One proposed solution to the problem of global warming involves the seeding of the atmosphere with metallic particles. One technique proposed to seed the metallic particles was to add the tiny particles to the fuel of jet airliners, so that the particles would be emitted from the jet engine exhaust while the airliner was at its cruising altitude. While this method would increase the reflection of visible light incident from space, the metallic particles would trap the long wavelength blackbody radiation released from the earth. This could result in net increase in global warming.

It is therefore an object of the present invention to provide a method for reduction of global warming due to the greenhouse effect which permits heat to escape through the atmosphere.

SUMMARY OF THE INVENTION

A method is disclosed for reducing atmospheric warming due to the greenhouse effect resulting from a greenhouse gases layer. The method comprises the step of seeding the greenhouse gas layer with a quantity of tiny particles of materials characterized by wavelength-dependent emissivity or reflectivity, in that said materials have high emissivities in the visible and far infrared wavelength regions and low emissivity in the near infrared wavelength region. Such materials can include the class of materials known as Welsbach materials. The oxides of metal, e.g., aluminum oxide, are also suitable for the purpose. The greenhouse gases layer typically extends between about seven and thirteen kilometers above the earth's surface. The seeding of the stratosphere occurs within this layer. The particles suspended in the stratosphere as a result of the seeding provide a mechanism for converting the blackbody radiation emitted by the earth at near infrared wavelengths into radiation in the visible and far infrared wavelength so that this heat energy may be reradiated out into space, thereby reducing the global warming due to the greenhouse effect.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features and advantages of the present invention will become more apparent from the following detailed description of an exemplary embodiment thereof, as illustrated in the accompanying drawings, in which:

FIG. 1 illustrates a model for the heat trapping phenomenon, i.e., the greenhouse effect.

FIG. 2 is a graph illustrating the intensity of sunlight incident on earth and of the earth's blackbody radiation as a function of wavelength.

FIG. 3 is a graph illustrating an ideal emissivity versus wavelength function for the desired particle material.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 shows a model for the heat-trapping (greenhouse effect) phenomenon. It is assumed that the greenhouse gases are concentrated at altitudes between $y=0$ (at some altitude Y_1, above the earth's surface) and $y=1$. Regardless of the sunshine reflected back into space, i_1 and i_2 denote the shortwavelength sunlight energies that are absorbed by the earth's surface and the greenhouse gases, respectively. Available data shows that $i_1=0.45\ i_{sol}$ and $i_2=0.25\ i_{sol}$, where i_{sol} is the total flux from the sun. The short wavelength sunlight heats up the greenhouse gases and the earth surface, and this energy is eventually reradiated out in the long wavelength infrared region.

FIG. 2 is a graph illustrating the intensity of sunlight and the earth's blackbody radiation as a function of wavelength. As illustrated, some 30% of the sunlight energy is in the near infrared region. The earth's blackbody radiation, on the other hand, is at the far infrared wavelength.

Referring again to FIG. 1, I_s, I_+, I_-, I_g and I_e represent the fluxes in the infrared wavelength region, where I_s and I_g are the fluxes reradiated by the greenhouse gases toward the sky and ground, respectively; I_e is the flux reradiated by the earth; and I_+ and I_- are fluxes within the gases radiating toward the space and ground, respectively. I_+ and I_- are functions of y, e.g., $I_+(0)$ is the I_+ flux at $y=0$. Considering the principles of energy conservation and continuity at boundaries, the following relationships are obtained:

$$I_s=i_1+i_2 \tag{1}$$

$$I_s=I_+(1)(1-R_l) \tag{2}$$

$$I_-(1)=I_+(1)R_l \tag{3}$$

$$I_+(0)=I_-(0)R_o+I_e(1-R_o) \tag{4}$$

$$I_g=I_-(0)(1-R_o)+I_eR_o \tag{5}$$

$$I_e=I_{BB}(T_e)(1-R)+I_gR \tag{6}$$

$$I_e=i_1+I_g \tag{7}$$

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where R_o, R_l and R are the reflectivities at the y=0 and y=1 boundaries and at the earth's surface. $I_{BB}(T_e)$ is the blackbody radiation flux at the earth's temperature T_e. Within the greenhouse gases' layer, the energy equations are

$$(dI_+/dy) = I_{BB}(T_g) - \alpha I_+ \quad (8)$$

$$-(dI_-/dy) = I_{BB}(T_g) - \alpha I_- \quad (9)$$

where $I_{BB}(T_g)$ is the blackbody radiation flux at the greenhouse gases' temperature T_g, and α is the absorption coefficient of the gases. The solutions of equations 8 and 9 are given by equations 10 and 11:

$$I_+(y) = (I_{BB}/\alpha) + Ce^{\alpha y} \quad (10)$$

$$I_-(y) = (I_{BB}/\alpha) + De^{+\alpha y} \quad (11)$$

To illustrate the effects of R_o and R_l on the greenhouse effect, the extreme case is considered wherein a high concentration of greenhouse gases has strong absorption in the infrared region; that is, for y=1, $e^{-\alpha l}$ approaches 0. Then, using Equations 3 and 4, the relationships of Equations 12 and 13 are obtained.

$$C = (I_e - (I_{BB}/\alpha))(1 - R_o) \quad (12)$$

$$D = 0$$

From Equations 5 and 7,

$$I_e = i_1 + I_-(0)(1 - R_o) + I_e R_o,$$

or

$$I_e = (i_1/(1 - R_o)) + (I_{BB}/\alpha). \quad (14)$$

From Equations 2 and 1,

$$I_t = (I_{BB}/\alpha)(1 - R_l) = i_1 + i_2,$$

or

$$(I_{BB}/\alpha) = (i_1 + i_2)/(1 - R_l). \quad (15)$$

Combining Equations 14 and 15, the relationship of Equation 16 is obtained.

$$I_e = i_1/(1 - R_o) + (i_1 + i_2)/(1 - R_l) \quad (16)$$

Finally, Equation 6 gives the blackbody radiation from the earth's surface in terms of i_1 and i_2 and the three reflectivities:

$$I_e = I_{BB}(T_e)(1 - R) + (I_e - i_1)R$$

$$I_{BB}(T_e) = I_e + (R/(1 - R))i_1$$

or

$$I_{BB}(T_e) = i_1/(1 - R_o) + (i_1 + i_2)/(1 - R_l) + (R/(1 - R))i_1 \quad (17)$$

To achieve a lower temperature of the earth, (considering i_1, i_2 and R as constants), it is desirable to make R and R_l as small as possible.

Known refractory materials have a thermal emissivity function which is strongly wavelength dependent. For example, the materials may have high emissivity (and absorption) at the far infrared wavelengths, high emissivity in the visible wavelength range, and very low emissivity at intermediate wavelengths. If a material having those emissivity characteristics and a black body are exposed to IR energy of equal intensity, the selective thermal radiator will emit visible radiation with higher efficiency (if radiation cooling predominates), i.e., the selective thermal radiator will appear brighter than the black body. This effect is known as the Welsbach effect and is extensively used in commercial gas lantern mantles.

Welsbach materials have the characteristic of wavelength-dependent emissivity (or reflectivity). For example, thorium oxide (ThO_2) has high emissivities in the visible and far IR regions but it has low emissivity in the near IR region. So, in accordance with the invention, the layer of greenhouse gases is seeded with Welsbach or Welsbach-like materials which have high emissivities (and thus low reflectivities) in the visible and 8–12 micrometer infrared regions, which has the effect of reducing R_o and R_l while introducing no effect in the visible range.

A desired material for the stratospheric seeding has a reflection coefficient close to unity for near IR radiation, and a reflection coefficient close to zero (or emissity close to unity) for far IR radiation. FIG. 3 is a graph illustrating an ideal emissivity versus wavelength function for the desired material. Another class of materials having the desired property includes the oxides of metals. For example, aluminum oxide (Al_2O_3) is one metal oxide suitable for the purpose and which is relatively inexpensive.

It is presently believed that particle sizes in the ten to one hundred micron range would be suitable for the seeding purposes. Larger particles would tend to settle to the earth more quickly.

The particles in the required size range can be obtained with conventional methods of grinding and meshing.

It is believed that the number of particles n_d per unit area in the particle layer should be defined by Equation 18:

$$n_d l \geqq 1/\sigma_{abs} \quad (18)$$

where l is the thickness of the particle layer and σ_{abs} is the absorption coefficient of the particles at the long IR wavelengths. One crude estimate of the density of particles is given by Equation (19):

$$n_d l \geqq (cmw)/(4\pi e^2) \quad (19)$$

where c is the speed of light, m is the average particle mass, e is the electron charge, and w is the absorption line width in sec^{-1}.

The greenhouse gases are typically in the earth's stratosphere at an altitude of seven to thirteen kilometers. This suggests that the particle seeding should be done at an altitude on the order of 10 kilometers. The particles may be seeded by dispersal from seeding aircraft; one exemplary technique may be via the jet fuel as suggested by prior work regarding the metallic particles. Once the tiny particles have been dispersed into the atmosphere, the particles may remain in suspension for up to one year.

It is understood that the above-described embodiment is merely illustrative of the possible specific embodiments which may represent principles of the present invention. Other arrangements may readily be devised in accordance with these principles by those skilled in the art without departing from the scope and spirit of the invention.

What is claimed is:

1. A method of reducing atmospheric warming due to the greenhouse effect resulting from a layer of gases in the atmosphere which absorb strongly near infrared wavelength radiation, comprising the step of dispersing tiny particles of a material within the gases' layer, the particle material characterized by wavelength-dependent emissivity or reflectivity, in that said material has high emissivities with respect to radiation in the visible and far infrared wavelength spectra, and low emissivity in the near infrared wavelength spectrum, whereby said tiny particles provide a means for converting infrared heat energy into far infrared radiation which is radiated into space.

2. The method of claim wherein said material comprises one or more of the oxides of metals.

3. The method of claim 1 wherein said material comprises aluminum oxide.

4. The method of claim 1 wherein said material comprises thorium oxide.

5. The method of claim 1 wherein said particles are dispersed by seeding the stratosphere with a quantity of said particles at altitudes in the range of seven to thirteen kilometers above the earth's surface.

6. The method of claim 1 wherein the size of said particles is in the range of ten to one hundred microns.

7. The method of claim wherein said material comprises a refractory material.

8. The method of claim 1 wherein said material is a Welsbach material.

9. The method of claim 1 wherein the number of said dispersed particles per unit area in the particle layer is greater than or equal to $1/\sigma_{abs}l$, where l is the thickness of the particle layer and σ_{abs} is the absorption coefficient of the particles at the far infrared wavelengths.

10. A method for reducing atmospheric warming due to the greenhouse effect resulting from a greenhouse gases layer, comprising the following step:

seeding the greenhouse gases' layer with a quantity of tiny particles of a material characterized by wavelength-dependent emissivity or reflectivity, in that said materials have high emissivities in the visible and far infrared wavelength spectra and low emissivity in the near infrared wavelength spectrum,

whereby said particles are suspended within said gases' layer and provide a means for converting radiative energy at near infrared wavelengths into radiation at the far infrared wavelengths, permitting some of the converted radiation to escape into space.

11. The method of claim 10 wherein said material comprises one or more of the oxides of metals.

12. The method of claim 10 wherein said material comprises aluminum oxide.

13. The method of claim 10 wherein said material is thorium oxide.

14. The method of claim 10 wherein said seeding is performed at altitudes in the range of seven to thirteen kilometers above the earth's surface.

15. The method of claim 10 wherein said material comprises a refractory material.

16. The method of claim 10 wherein said particle size is in range of ten to one hundred microns.

17. The method of claim 10 wherein said material is a Welsbach material.

18. The method of claim 10 wherein the number of said dispersed particles per unit area in the particle layer is greater than or equal to $1/\sigma_{abs}$ l, where l is the thickness of the particle layer and σ_{abs} is the absorption coefficient of the particles at the far infrared wavelengths.

* * * * *

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APPENDIX 15

XV, 2

United States Patent [19]

Werle et al.

[11] **3,899,144**

[45] **Aug. 12, 1975**

[54] **POWDER CONTRAIL GENERATION**

[75] Inventors: **Donald K. Werle**, Hillside; **Romas Kasparas**, Riverside; **Sidney Katz**, Chicago, all of Ill.

[73] Assignee: **The United States of America as represented by the Secretary of the Navy**, Washington, D.C.

[22] Filed: **July 22, 1974**

[21] Appl. No.: **490,610**

[52] **U.S. Cl.**............... **244/136;** 40/213; 116/114 F; 241/5

[51] **Int. Cl.²**... **B64D 1/16**

[58] **Field of Search**........... 244/136; 40/213; 241/5, 241/29; 222/3, 4; 239/171; 116/28 R, 114 R, 114 F, 114 N, 124 R, 124 B, 124 C

[56] **References Cited**

UNITED STATES PATENTS

1,619,183	3/1927	Bradner et al.	244/136
2,045,865	6/1936	Morey	40/213
2,591,988	4/1952	Willcox	241/5 X
3,531,310	9/1970	Goodspeed et al.	241/5 X
R15,771	2/1924	Savage	40/213

FOREIGN PATENTS OR APPLICATIONS

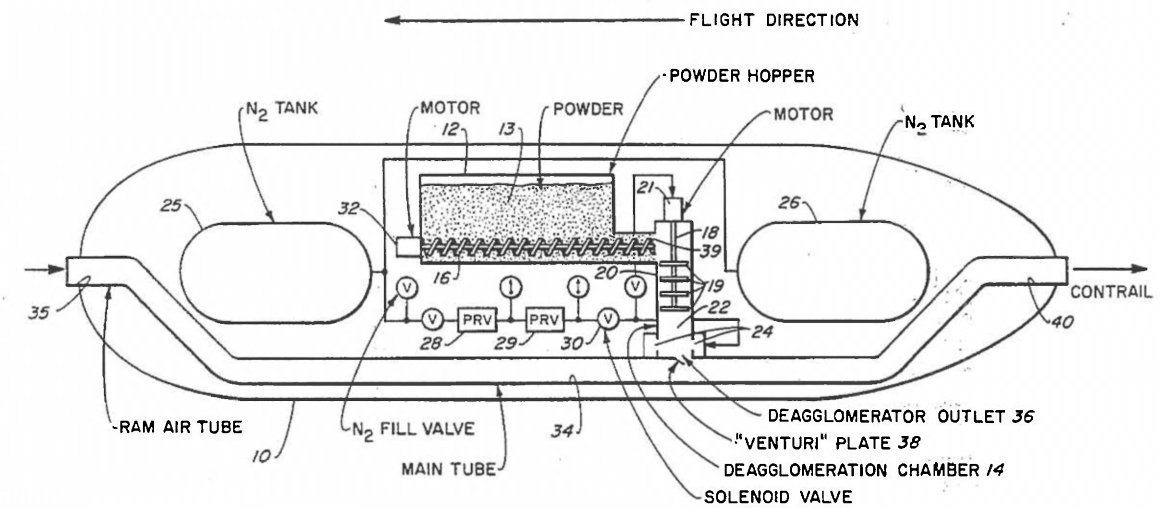
1,022,621	3/1966	United Kingdom	241/5

Primary Examiner—Trygve M. Blix
Assistant Examiner—Barry L. Kelmachter
Attorney, Agent, or Firm—Richard S. Sciascia; Joseph M. St. Amand

[57] **ABSTRACT**

Light scattering pigment powder particles, surface treated to minimize interparticle cohesive forces, are dispensed from a jet mill deagglomerator as separate single particles to produce a powder contrail having maximum visibility or radiation scattering ability for a given weight material.

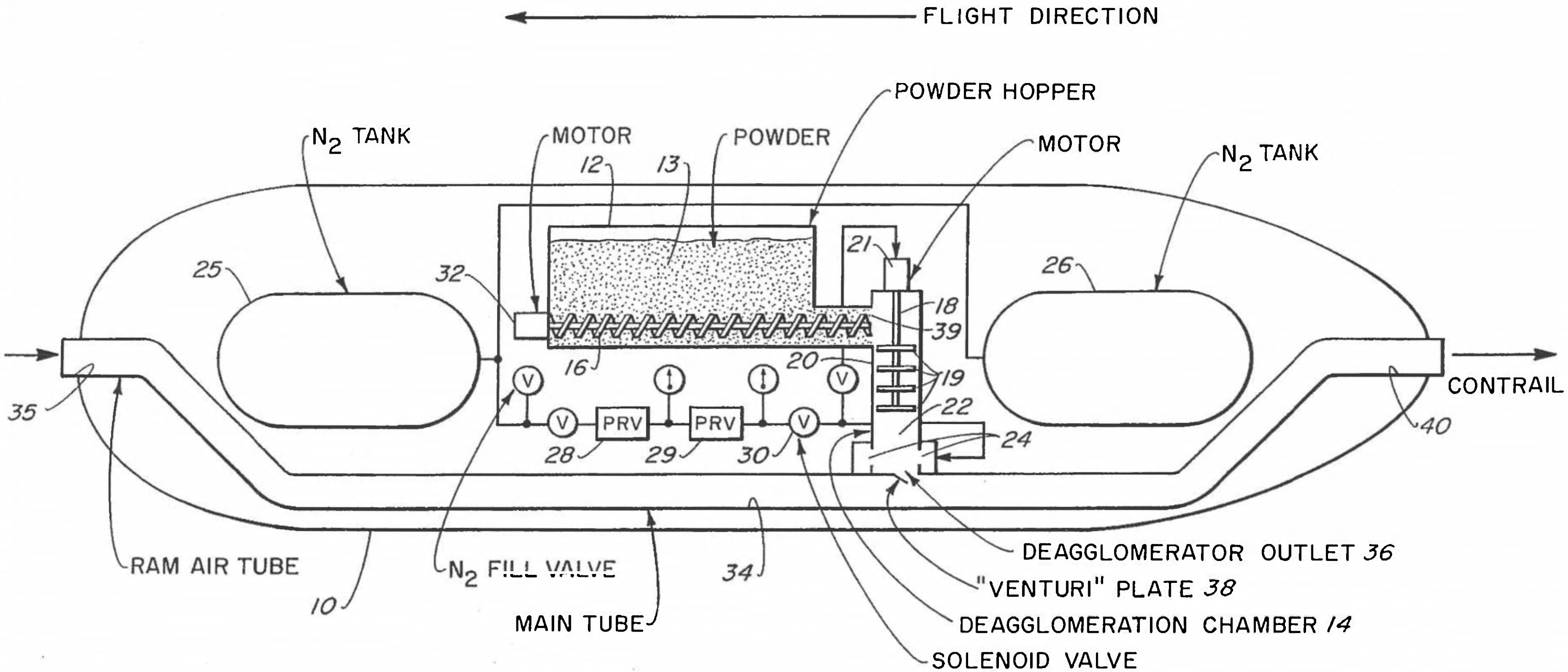
12 Claims, 1 Drawing Figure



PATENTED AUG 12 1975

3,899,144

Fig. 1.



XV, 3

POWDER CONTRAIL GENERATION

BACKGROUND

The present invention relates to method and apparatus for contrail generation and the like.

An earlier known method in use for contrail generation involves oil smoke trails produced by injecting liquid oil directly into the hot jet exhaust of an aircraft target vehicle. The oil vaporizes and recondenses being the aircraft producing a brilliant white trail. Oil smoke trail production requires a minimum of equipment; and, the material is low in cost and readily available. However, oil smoke requires a heat source to vaporize the liquid oil and not all aircraft target vehicles, notably towed targets, have such a heat source. Also, at altitudes above about 25,000 feet oil smoke visibility degrades rapidly.

SUMMARY

The present invention is for a powder generator requiring no heat source to emit a "contrail" with sufficient visibility to aid in visual acquisition of an aircraft target vehicle and the like. The term "contrail" was adopted for convenience in identifying the visible powder trail of this invention. Aircraft target vehicles are used to simulate aerial threats for missile tests and often fly at altitudes between 5,000 and 20,000 feet at speeds of 300 and 400 knots or more. The present invention is also suitable for use in other aircraft vehicles to generate contrails or reflective screens for any desired purpose.

The powder contail generator is normally carried on an aircraft in a pod containing a ram air tube and powder feed hopper. Powder particles, surface treated to minimize interparticle cohesive forces are fed from the hopper to a deagglomerator and then to the ram air tube for dispensing as separate single particles to produce a contrail having maximum visibility for a given weight material.

Other object, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawing.

DESCRIPTION OF DRAWING

FIG. 1 is a schematic sectional side-view of a powder contrail generator of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENT

The powder contail generator in pod **10,** shown in FIG. **1,** is provided with a powder feed hopper **12** positioned in the center section of the pod and which feeds a powder **13** to a deagglomerator **14** by means of screw conveyors **16** across the bottom of the hopper. The deagglomerator **14** produces two stages of action. In the first stage of deagglomeration, a shaft **18** having projecting radial rods **19** in compartment **20** is rotated by an air motor **21,** or other suitable drive means. The shaft **18** is rotated at about 10,000 rpm, for example. As powder **13** descends through the first stage compartment **20** of the deagglomeration chamber, the hammering action of rotating rods **19** serves to aerate and precondition the powder before the second stage of deagglomeration takes place in the jet mill section **22.** In the jet mill **22,** a plurality of radial jets **24** (e.g., six 0.050 inch diamter radial jets) direct nitrogen gas (at e.g., 120 psig) inward to provide energy for further deagglomeration of the powder. The N_2, or other suitable gas, is provided from storage tanks **25** and **26,** for example, in the pod.

The jet mill **22** operates in a similar manner to commercial fluid energy mills except that there is no provision for recirculation of oversize particles. Tests with the deagglomerator show that at a feed rate of approximately 1½ lb/min, treated titanium dioxide powder pigment is effectively dispersed as single particles with very few agglomerates evident.

The nitrogen gas stored in cylinder tanks **25** and **26** is charged to 1800 psig, for example. Two stages of pressure reduction, for example, by pressure reduction valves **28** and **29,** bring the final delivery pressure at the radial jets **24** and to the air motor **21** to approximately 120 psig. A solenoid valve **30** on the 120 psig line is connected in parallel with the electric motor **32** which operates the powder feeder screws **16** for simultaneous starting and running of the powder feed, the air motor and the jet mill deagglomerator.

Air enters ram air tube **34** at its entrance **35** and the exhaust from the jet mill deagglomerator passes directly into the ram air tube. At the deagglomerator exhaust **36** into ram air tube **34,** an upstream deflector baffle **38** produces a venturi effect which minimizes back pressure on the powder feed system. The powder is then jetted from the exhaust end **40** of the ram air tube to produce a contrail. A pressure equalization tube, not shown, can be used to connect the top of the closed hopper **12** to the deagglomeration chamber **14.** A butterfly valve could be provided at the powder hopper outlet **39** to completely isolate and seal off the powder supply when not in use. Powder **13** could then be stored in hopper **12** for several weeks, without danger of picking up excessive moisture, and still be adequately dispensed.

Preparation of the light scatter powder **13** is of a critical importance to production of a powder "contrail" having maximum visibility for a given weight of material. It is essential that the pigment powder particles be dispensed as separate single particles rather than as agglomerates of two or more particles. The powder treatment produces the most easily dispersed powder through the use of surface treatments which minimize interparticle cohesive forces.

Titanium dioxide pigment was selected as the primary light scattering material because of its highly efficient light scattering ability and commercially available pigment grades. Titanium dioxide pigment (e.g., DuPont R—931) with a median particle size of about 0.3μ has a high bulk density and is not readily aerosolizable as a submicron cloud without the consumption of a large amount of deagglomeration energy. In order to reduce the energy requirement for deagglomeration, the TiO_2 powder is specially treated with a hydrophobic colloidal silica which coats and separates the individual TiO_2 pigment particles. The extremely fine particulate nature (0.007μ primary particle size) of Cobot S—101 Silanox grade, for example, of colloidal silica minimizes the amount needed to coat and separate the TiO_2 particles, and the hydrophobic surface minimizes the affinity of the powder for absorbtion of moisture from the atmosphere. Adsorbed moisture in powders causes liquid bridges at interparticle contacts and it then becomes necessary to overcome the adsorbed-liquid surface tension forces as well as the weaker Van der Waals' forces before the particles can be separated.

The Silanox treated titanium dioxide pigment is further protected from the deleterious effects of adsorbed moisture by incorporation of silica gel. The silica gel preferentially adsorbs water vapor that the powder may be exposed to after drying and before use. The silica gel used is a powder product, such as Syloid 65 from the W. R Grace and Co., Davison Chemical Division, and has an average particle size about 4.5μ and a large capacity for moisture at low humidities.

A typical powder composition used is shown in Table 1. This formulation was blended intimately with a Patterson-Kelley Co. twin shell dry LB–model LB—2161 with intensifier. Batches of 1500 g were blended for 15 min. each and packaged in 5-lb cans. The bulk density of the blended powder is 0.22 g/cc. Since deagglomeration is facilitated by having the powder bone dry, the powder should be predried before sealing the cans. In view of long periods (e.g., about 4 months) between powder preparation and use it is found preferable to spread the powder in a thin layer in an open container and place in a 400°F over two days before planned usage. The powder is removed and placed in the hopper about 2 hours before use.

Table 1

CONTRAIL POWDER FORMULATION

Ingredient	% by Weight
TiO_2 (e.g., DuPont R-931) median particle size 0.3μ	85
Colloidal Silica (e.g., Cabot S-101 Silanox) primary particle size 0.007μ	10
Silica gel (e.g., Syloid 65) average particle size 4.5μ	5

Other type powder compositions can also be used with the apparatus described herein. For example, various powder particles which reflect electromagnetic radiation can be dispensed as a chaff or the like from the contrail generator.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claim is:

1. Contrail generation apparatus for producing a powder contrail having maximum radiation scattering ability for a given weight material, comprising:

a. an aerodynamic housing;

b. a jet tube means passing through said housing, said tube means having an inlet at a forward end of said housing and an exhaust at a rearward end thereof;

c. a powder storage means in said housing;

d. a deagglomeration means also in said housing;

e. means connecting said powder storage means with said deagglomeration means for feeding radiation scattering powder from said powder storage means to said deagglomeration means;

f. the output of said deagglomeration means dispensing directly into said jet tube means for exhausting deagglomerated powder particles into the atmosphere to form a contrail; and

h. means for controlling the flow of said powder from said storage means to said deagglomeration means.

2. Apparatus as in claim **1** wherein said jet tube means is a ram air jet tube.

3. Apparatus as in claim **1** wherein an upstream deflector baffle is provided at the output of said deagglomeration means into said jet tube means to produce a venturi effect for minimizing back pressure on said powder feeding means.

4. Apparatus as in claim **1** wherein said deagglomerator means comprises:

a. means for subjecting powder particles from said powder storage means to a hammering action to aerate and precondition the powder; and

b. a jet mill means to further deagglomerate the powder into separate particles.

5. Apparatus as in claim **4** wherein pressurized gas means is provided for operating said deagglomeration means.

6. Apparatus as in claim **1** wherein said radiation scattering powder particles are titanium dioxide pigment having a median particle size of about 0.3 microns.

7. Apparatus as in claim **1** wherein said radiation scattering powder particles have a coating of extremely fine hydrophobic colloidal silica thereon to minimize interparticle cohesive forces.

8. Apparatus as in claim **1** wherein the formulation of said powder consists of 85% by weight of TiO_2 pigment of approximately 0.3 micron media particle size, 10% by weight of colloidal silica of 0.007 micron primary particle size, and 5% by weight of silica gel having an average particle size of 4.5 microns.

9. The method of producing a light radiation scattering contrail, comprising:

a. surface treating light scattering powder particles to minimize interparticle cohesive forces;

b. deagglomerating said powder particles in two stages prior to dispensing into a jet tube by subjecting said powder particles to a hammering action in the first stage to aerate and precondition the powder, and by passing said powder through a jet mill in the second stage to further deagglomerate the powder;

c. dispensing the deagglomerated powder from the jet mill directly into a jet tube for exhausting said powder into the atmosphere, thus forming a contrail.

10. A method as in claim **9** wherein said light scattering powder particles is titanium dioxide pigment.

11. A method as in claim **9** wherein said powder particles are treated with a coating of extremely fine hydrophobic colloidal silica to minimize interparticle cohesive forces.

12. A method as in claim **11** wherein said treated powder particles are further protected with a silica gel powder.

* * * * *

XV, 5

XVI, 1

APPENDIX 16

XVI, 2

AIRWORK
PILOTEN PORTAL

Chemtrails...wie weet er meer van?

Post Reply

#71

Beer
Contact Houston Space Center

Airworker sinds: Dec 1999
Locatie: SPL
Berichten: 1.347
Brevet: JAA CPL/IR/ME (frozen ATPL)
Typeratings: Fokker 50
Uren: 1400+

Citaat:

> Origineel gepost door **Okki**
> *Hebben jullie trouwens al dat nieuwe X-432 gespoten?*

Nee... ik kom niet van de KLS, dus ik ben niet goed genoeg voor dat spul.

Quote

#70

PH-JPC
Contact Houston Space Center

Airworker sinds: Jan 2003
Locatie: 2 rood, 2 wit, slightly right
Berichten: 1.411
Brevet: met bloed zweet en tranen verkregen
Typeratings: De laatste jaren in een stofzuiger ver boven het weer en het terrein. Ver weg van de avonturen die ik daarvóór heb mogen beleven en waar ik nog dagelijks aan terug denk
Uren: In verhouding met mijn leeftijd redelijk wat

Dat dat zomaar bekend is bij jou... ik weet alleen dát ik moet lozen en wáár. Nog nooit iemand gekend die meer info had!
Maar wel interessant moet ik zeggen.

Diana, misschien toch een idee om dit forum gesloten te maken zodat niet iedereen deze gevoelige info kan lezen?

Quote

#69

XVI, 3

Okki
cleared FL 200

Airworker sinds: May 2001
Locatie: Nederland
Berichten: 536
Brevet: ATPL
Typeratings: Suck, Squeeze & Blow
Uren: 70 per maand

Hebben jullie trouwens al dat nieuwe X-432 gespoten?

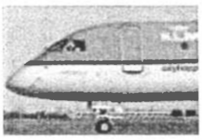
't schijnt in elk geval beter te werken dan die oude rommel die we hadden. Minder bijwerkingen als huidkanker en TBC!

Mijn operator denkt na over de aanschaf omdat de EU ons meer slots wil geven overal door europa als we er mee gaan spuiten!

Quote

[illegible]-04-2007, 15:53 #68

Eikie
Contact Houston Space Center



Airworker sinds: May 2000
Locatie: SPL
Berichten: 1.160
Brevet: ja
Typeratings: F50/E190
Uren: 2000+

Citaat:

> Origineel gepost door **49015**
> *Nu we het er toch over hebben, heeft een van jullie wel eens zijn eigen chemtrail gezien? Hoe ik mijn best ook doe (bijvoorbeeld achterom kijken tijdens een bocht), mijn eigen trail heb ik nog nooit gezien.*

Dat komt omdat chemtrails, in tegenstelling tot contrails, een langere levensduur hebben. Chemtrails verwaaien vaak tot wat amateurs en onwetenden cirrus noemen. (wij weten beter).

"Nadeel" is echter wel dat ze ook pas later zichtbaar zijn dan contrails, zeker als je er niet van onderen tegen aan kijkt. (heeft met de lichtabsorbtie te maken, asymetrische moleculen)

Quote

13-04-2007, 15:52 #67

Phoenix_X
Optimum Flightlevel

Airworker sinds: Nov 1999
Locatie: EU
Berichten: 956
Brevet: ATPL
Typeratings: A320 (737)
Uren: Flink minder dan 100.000

Citaat:

> Origineel gepost door **Pjotr Orno**
> *Hebben jullie nooit last van die vliegende schotels die de laatste tijd overal voorbij schieten? Ik zou het niet meer dan normaal vinden als zij ook verplicht een transponder aan boord moeten hebben. Dit gaat natuurlijk nog een keer fout.*
>
> *Het sprayen zelf heb ik overigens niet veel problemen mee, hooguit dat je af en toe een dubbele flame-out hebt van die chemische deeltjes.*

Jij leest blijkbaar ook nooit de NOTAMS. Er staat duidelijk in dat hier over gedacht is maar dat de investering voor de (niet nader te noemen) "operators" van deze schotels te hoog zou zijn. Zeker aangezien we richting ADS-B gaan en de volgende generatie comms (zoals datalink etc). Het is de bedoeling dat deze systemen wel verplicht gaan worden voor dit SP-TFC (Special Traffic). Dit zou rond 2015 moeten zijn, dus het blijft nog even opletten.

Die datalink wordt trouwens ook belangrijk voor de chemtrails. Bij mijn vorige airline vlogen we ook over China en daar wordt de datalink gebruikt om de mixture van de chemtrails in real-time aan te passen vanaf de grond. Het handmatig aanpassen van settings van de chemtrails (zelfs in non-normals) is niet toegestaan en moet via datalink aangevraagd worden. Ik zie dat hier ook wel gebeuren; aangezien ik vorige week op kantoor moest komen samen met de cpt om uit te leggen waarom wij na een (3.1) CHEM DISP Illuminati de boel af hadden gezet. Blijkbaar heeft dat verstrekkende gevolgen voor het welbekende "big picture."

Quote

[illegible]-04-2007, 15:39 #66

49015
Contact Houston Space Center

Airworker sinds: Oct 2001
Locatie: Gelukkig niet meer in La Perla
Berichten: 1.243

Nu we het er toch over hebben, heeft een van jullie wel eens zijn eigen chemtrail gezien? Hoe ik mijn best ook doe (bijvoorbeeld achterom kijken tijdens een bocht), mijn eigen trail heb ik nog nooit gezien.

XVI, 4

Brevet: ATPL
Typeratings: De families 320 en 737
Uren: 4,5K zonder crew rest!

Quote

#63

digits
1500 ft

Airworker sinds: Apr 2006
Locatie: Belgie
Berichten: 199
Brevet: ppl
Typeratings: none
Uren: veel te weinig

Citaat:

> 4 LIMITATIONS AND SYSTEM DATA
>
> - The CHEMICAL DISPENSER can be used in the air only.
> - If crosswind components at >FL100 exceed 15 kts operation is not advised.
> - Bleed air can be supplied in air for 3 packs and in flight till 15000 ft press. altitude for 1 pack.
> - Each CHEMICAL DISPENSER is supplied with 2 bottles; 1 bottle can be used for approx 666 sq. km.
> - In case pax discretion is violated, advise Chemtrail Operations immidiatly and have pax diagnosed with any mental illness.
> - If possible, a grid flightpath is to be followed. Air Traffic Control is obliged to cooperate. Extended flight times (delays) may be blamed on Air Traffic Control, Ground Employees and weather.
> - It's the Commander's responsibility that Chemical Operations are done in accordence with the AOM, and within the time limits stated by the New World Order.
> - When Chemical Operations are in progress, Bilderberg accomodation may be used during nightstops only.
>
> If questions arise, contact +1 800 NEW WORLD (+1 800 NEW WORLD)

zalig :p

Quote

#64

Flying Dutchman
In orbit

Airworker sinds: Aug 2001
Locatie: Suburbia, USA
Berichten: 3.550
Brevet: The ones that let me fly for hire.
Typeratings: Singles and twins, pistons and turbines, right seat and left seat.
Uren: 7 years and counting

Citaat:

> Origineel gepost door **kermit**
> *. Nu is het zo erg dat ik al een paar maanden op de grond sta. Brevet ingetrokken wegens psychische instabiliteit en ondertussen ook een Prozac grootgebruiker geworden..*

Join de club ouwe...
See ya next monday at the dokter!

Citaat:

> Origineel gepost door **Q-nimbus**
> *De grond wordt me te heet onder de voeten...*
>
> *Iedere keer als ik bel of word gebeld, hoor ik nu zo'n rare klik. Ook vond ik sigaretten peuken bij de deur, en wil een mysterieuze man, die zichzelf 'Deep Throat' noemt, ergens op een openbare plek met me afspreken.*

Blij dat je Art ook een keer ontmoet hebt....

Quote

#65

kermit
Optimum Flightlevel

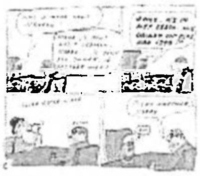
Airworker sinds: Apr 2000
Locatie: Zuid Holland
Berichten: 879
Brevet: ATPL
Typeratings: Airbus 320, Boeing 737, 757, 777
Uren: 4500+

Quote

12-04-2007, 19:46 #62

XVI, 5

Pjotr Orno
over to departure



Airworker sinds: Jan 2005
Locatie: Amsterdam
Berichten: 213
Brevet: FATPL
Typeratings: 4 motoren
Uren: 1500+

Dus voortaan kunnen we je aanspreken als Miss Piggy?

Quote

12-04-2007, 19:34 #61

kermit
Optimum Flightlevel

Airworker sinds: Apr 2000
Locatie: Zuid Holland
Berichten: 879
Brevet: ATPL
Typeratings: Airbus 320, Boeing 737, 757, 777
Uren: 4500+

Het is goed dat het een keer openlijk besproken wordt. Heb de laatste maanden ernstig last van mijn geweten gekregen. Al die ellende die we aanrichten, kinderen, dieren etc. De lange termijn gevolgen zijn niet te overzien.

In het begin had ik er eigenlijk geen last van. Ja, je weet het wel maar ja, je jaagt toch die droom na. Sinds ik vader geworden ben is het gaan knagen. Nu is het zo erg dat ik al een paar maanden op de grond sta. Brevet ingetrokken wegens psychische instabiliteit en ondertussen ook een Prozac grootgebruiker geworden.

Het probleem is dat je er niet over kunt praten dus bij de hulpverleners heb ik maar verteld dat ik denk dat ik in het verkeerde lichaam geboren ben.

Nu het 'in the open' is hoop ik dat meer lotgenoten zich melden zodat we door er met elkaar over te spreken uit dit diepe dal kunnen komen.

Gegroet.

Quote

12-04-2007, 15:57 #60

Radix
over to departure

Airworker sinds: Jul 2004
Locatie: Down under
Berichten: 299
Brevet: -
Typeratings: -
Uren: -

Nu snap ik ook waarom ze bij mijn psychologische keuring zaken als betrouwbaarheid en discretie in het rapport noemden. Ik scoorde daar niet zo hoog op, en wat denk je: resultaat twijfelachtig!!!

Maar nu ik zie dat er hier zo open over gesproken wordt ga ik ze hier zeker mee confronteren! Je hoort er nog van.

Quote

12-04-2007, 14:19 #59

Pjotr Orno
over to departure

Airworker sinds: Jan 2005
Locatie: Amsterdam
Berichten: 213
Brevet: FATPL
Typeratings: 4 motoren
Uren: 1500+

Hebben jullie nooit last van die vliegende schotels die de laatste tijd overal voorbij schieten? Ik zou het niet meer dan normaal vinden als zij ook verplicht een Transponder aan boord moeten hebben. Dit gaat natuurlijk nog een keer fout.

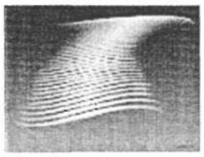
Het sprayen zelf heb ik overigens niet veel problemen mee, hooguit dat je af en toe een dubbele flame-out hebt van die chemische deeltjes.

Quote

XVI, 6

Quote

Q-nimbus
Contact Houston Space Center



Airworker sinds: Jun 2006
Locatie: Camp X-Ray
Berichten: 1.359
Brevet: ATPL
Typeratings: B777-200/300
Uren: 60-70 per maand

De grond wordt me te heet onder de voeten...

Iedere keer als ik bel of word gebeld, hoor ik nu zo'n rare klik. Ook vond ik sigaretten peuken bij de deur, en wil een mysterieuze man, die zichzelf 'Deep Throat' noemt, ergens op een openbare plek met me afspreken. Ook zit er een rare Amerikaan achter me aan, Sculder genaamd, die ook al iets van me moet.

Ik ga onderduiken!

Quote

Beer
Contact Houston Space Center

Airworker sinds: Dec 1999
Locatie: SPL
Berichten: 1.347
Brevet: JAA CPL/IR/ME (frozen ATPL)
Typeratings: Fokker 50
Uren: 1400+

Damn... hier ga je gelazer mee krijgen Q. De laatste keer dat ik een collega hierover hoorde praten, was ie de volgende dag van de aardbodem verdwenen.

Quote

PH-JPC
Contact Houston Space Center

Airworker sinds: Jan 2003
Locatie: 2 rood, 2 wit, slightly right
Berichten: 1.411
Brevet: met bloed zweet en tranen verkregen
Typeratings: De laatste jaren in een stofzuiger ver boven het weer en het terrein. Ver weg van de avonturen die ik daarvóór heb mogen beleven en waar ik nog dagelijks aan terug denk
Uren: In verhouding met mijn leeftijd redelijk wat

WTF waarom strooi je die dingen zomaar op internet??
Nou ja als jij het niet doet had een ander het wel gedaan waarschijnlijk...

(haha onder t genot van een biertje toch wel erg leuk om weer eens doorheen te lezen)

Wat ik me trouwens ook afvraag... de laatste jaren ben ik toch wel wat haren verloren... zou dat komen vanwege onze nieuwe operaties hiermee?

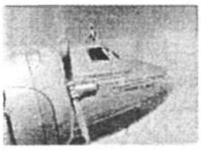
Quote

Flying Dutchman
In orbit

Als de pax eens wisten wat ze financieel mogelijk maken met die 'sky miles' van ze....

FD

XVI, 7

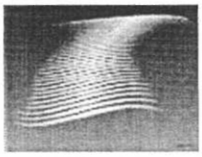


Airworker sinds: Aug 2001
Locatie: Suburbia, USA
Berichten: 3.550
Brevet: The ones that let me fly for hire.
Typeratings: Singles and twins, pistons and turbines, right seat and left seat.
Uren: 7 years and counting

Quote

12-04-2007, 00:09 #51

Q-nimbus
Contact Houston Space Center



Airworker sinds: Jun 2006
Locatie: Camp X-Ray
Berichten: 1.359
Brevet: ATPL
Typeratings: B777-200/300
Uren: 60-70 per maand

Wat dacht je van het Skyteam logo? Dat logo representateert een grote chemtrail!

Quote

12-04-2007, 00:06 #50

Flying Dutchman
In orbit

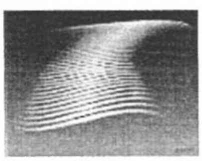
Airworker sinds: Aug 2001
Locatie: Suburbia, USA
Berichten: 3.550
Brevet: The ones that let me fly for hire.
Typeratings: Singles and twins, pistons and turbines, right seat and left seat.
Uren: 7 years and counting

Klopt, vandaar ook de eeuwen oude samenwerking met amstelveen/klm om de 'goods' te verspreiden over de hele wereld.... Als de mensen es echt wisten waar al die KLM/NWA logo's echt voor stonden op onze NWA (airlink) en KLM (cityhopper) toestellen over de hele wereld....

Quote

12-04-2007, 00:02 #49

Q-nimbus
Contact Houston Space Center



Airworker sinds: Jun 2006
Locatie: Camp X-Ray
Berichten: 1.359
Brevet: ATPL
Typeratings: B777-200/300
Uren: 60-70 per maand

North West Airlines = NWA.

Eigenlijk wilden ze er New World Order (NWO) van maken, maar dat was iets te doorzichtig voor de slimme complot geleerde.

XVI, 8

Quote

1-04-2007, 23:56 #48

Flying Dutchman
In orbit

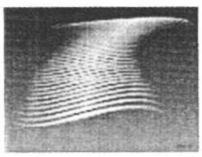
Airworker sinds: Aug 2001
Locatie: Suburbia, USA
Berichten: 3.550
Brevet: The ones that let me fly for hire.
Typeratings: Singles and twins, pistons and turbines, right seat and left seat.
Uren: 7 years and counting

zit chemtrail ops bij jullie op 124.42 ? (pm me anders ff)

Quote

11-04-2007, 23:48 #47

Q-nimbus
Contact Houston Space Center



Airworker sinds: Jun 2006
Locatie: Camp X-Ray
Berichten: 1.359
Brevet: ATPL
Typeratings: B777-200/300
Uren: 60-70 per maand

Citaat:

> Origineel gepost door **digits**
> *huh ? kan ik hieruit besluiten dat er echt zo een hoofdstuk in de Operations manual staat*
>
> *iemand enkele leuke quotes daar uit ? (of via pm)*
>
> *greetings,*
> *digits*

Operations Manual 8.4.3.5:

1. CHEMICAL DISPATCH (CHEMTRAIL) Operations

1.1 CHEMICAL DISPENSER NORMAL PROCEDURES
1.2 CHEMICAL DISPENSER SHUTDOWN

2. CONDITIONAL PROCEDURES

(NOT APPLICABLE)

3. ABNORMAL PROCEDURES

3.1 CHEMICAL DISPENSER
3.2 CHEMICAL DISPENSER DOOR
3.3 CHEMICAL DISPENSER FUEL

4. LIMITATIONS AND DATA

For normal Chemtrail Operation refer to AOM 8.4.3.5.1.

For maximum wind components refer to AOM 8.4.3.5.2.

For minima applicable to dispatch with equipment unservicable refer to AOM 2.6.

Minima due to abnormal aircraft configuration are published in the respective ECL procedure.

1.1 CHEMICAL DISPENSER NORMAL PROCEDURES

- CHEMICAL DISPENSER START (Air only)
- BAT P/B...CFRM ON
- STANDBY POWER SELECTOR..............CHEM DISP
- CHEMICAL DISPENSER.......................START
- MIXTURE.. ..SET
- CHEMICAL DISPENSER Selector..........OFF

Dispatch requirements:

- 8 Full bottles (a 666 sq. km = 5328 sq. km)

XVI, 9

- Check fluoride level in potable water is at least 4.5 %
- Refer to MEL 4.5 23-2

2. CONDITIONAL PROCEDURES

(Not Applicable)

3. ABNORMAL PROCEDURES

3.1 CHEM DISP

- This alert is Illuminati when:
- IQ selector is set to less than 23.
- Pax o/b who are the result of a marriage between cousins.

* CHEM DISP in ON position:

- CHEM DISP..O FF
- MIXTURE SELECTOR..............................DUMP

* Advise pax out of the blue that everything is in order.

CHEM DISP remains displayed

- No restart attempt should be made.

CHEM DISP no longer displayed

- CHEM DISP..ST ART
- Start attempts may be repeated
- Refer to Limitations and Systems data 2.4.4-4

Procedure completed

3.2 CHEM DISP DOOR

This alert is Illuminati when the CHEM DISP DOOR is not in the commanded position.

On ground:

- Contact NWO/MiB (VHF 151.51 or Grid number 51)

In air:

- Continue

Procedure completed.

**** Passenger discretion is advised ****

3.3 CHEMICAL DISPENSER FUEL

This alert is Illuminati when CHEMICAL DISPENSER Chemicals are low

- CHEM DISP SELECTOR.............................OFF
* No restart attempt should be made

- Refill as soon as possible. Diversions are optional, in concern with NWO Chemtrail Operations, Rachel, Nevada, USA.

Procedure completed.

4 LIMITATIONS AND SYSTEM DATA

- The CHEMICAL DISPENSER can be used in the air only.
- If Crosswind components at >FL100 exceed 15 kts operation is not advised.
- Bleed air can be supplied in air for 3 packs and in flight till 15000 ft press. altitude for 1 pack.
- Each CHEMICAL DISPENSER is supplied with 2 bottles; 1 bottle can be used for approx 666 sq. km.
- In case pax discretion Is violated, advise Chemtrail Operations immidiatly and have pax diagnosed with any mental illness.
- If possible, a grid flightpath is to be followed. Air Traffic Control is obliged to cooperate. Extended flight times (delays) may be blamed on Air Traffic Control, Ground Employees and weather.
- It's the Commander's responsibility that Chemical Operations are done in accordence with the AOM, and within the time limits stated by the New World Order.
- When Chemical Operations are in progress, Bilderberg accomodation may be used during nightstops only.

If questions arise, contact +1 800 NEW WORLD (+1 800 63996753)

XVI, 10

Ik weet dat ik hiermee het protocol negeer, maar ik kom de laatste tijd toch in gewetensnood.

Laatst aangepast door Q-nimbus : 13-04-2007 om 16:30

Quote

[illegible]-04-2007, 23:40 #48

Flying Dutchman
In orbit

Airworker sinds: Aug 2001
Locatie: Suburbia, USA
Berichten: 3.550
Brevet: The ones that let me fly for hire.
Typeratings: Singles and twins, pistons and turbines, right seat and left seat.
Uren: 7 years and counting

Ja, die staan inderdaad in onze OPS manuals, en nee vind het niet verstandig (ook niet via PM) om dit aan derden door te spelen.

Chemtrails heeft 2 hoofdstukken bij ons en is met name BUSSS (Because Uncle Sam Said So...) shit...

Voor de rest hebben we bij mijn maatschappij, wat het geval is bij meerdere maatschappijn, een contract moeten tekenen (twv 5.000.000 en/of 10 jaar celstraf!!) over het vrijgeven van de inhoud.

Wij krijgen elke 6 maanden naast de TSA anti terrorisme training ook elke 6 maanden (minimale) training over het chemtrail program van een paar manen in pak van een niet nader te noemen instantie.

Ik kan je vertellen, zoals hier eerder aangegeven, dat wij maar een minimaal 'amount' of information krijgen (need to know bases). En indd met name te horen krijgen over waar we wat en wanneer moeten doen.

Goed, FD is offline. FF wat gif over the lower 48 verspreiden.... Dacht dat onze vluchtnummers vandaag weer aan de beurt zijn om te sprayen... Because uncle Sam said so I guess.....

Sorry.
FD

edit: vind het ook niet echt bepaald slim van collega's om hier ook maar een beetje over vrij te geven maargoed, heb zelf ook alweer teveel gezegd. Whatever.

Laatst aangepast door Flying Dutchman : 11-04-2007 om 23:50

Quote

[illegible]-2007, 23:09 #45

digits
1500 ft

Airworker sinds: Apr 2006
Locatie: Belgie
Berichten: 199
Brevet: ppl
Typeratings: none
Uren: veel te weinig

Citaat:

> Origineel gepost door **Diana**
> *Jongens, hoe vaak moet ik nog zeggen dat er nog een echte wereld daarbuiten is? Je kunt hier niet alles zeggen. De betreffende pagina's noemen uit het Operations manual, daar wordt men niet vrolijk van. Ik krijg er alweer telefoon over. Hoe om te gaan met de media i.v.m. chemtrails is niet iets wat men op een publiek board terug wil zien.*

huh ? kan ik hieruit besluiten dat er echt zo een hoofdstuk in de Operations manual staat

iemand enkele leuke quotes daar uit ? (of via pm)

greetings,
digits

Quote

[illegible]-2007, 22:16 #44

Beer
Contact Houston Space Center

Airworker sinds: Dec 1999
Locatie: SPL
Berichten: 1.347
Brevet: JAA CPL/IR/ME (frozen ATPL)
Typeratings: Fokker 50
Uren: 1400+

Jup... wij zijn gewoon de trekpoppetjes die het uit mogen voeren. "De grote baas" zal wel een bedoeling ermee hebben.

Quote

XVI. 11

11-04-2007, 22:00 #43

PH-JPC
Contact Houston Space Center

Airworker sinds: Jan 2003
Locatie: 2 rood, 2 wit, slightly right
Berichten: 1.411
Brevet: met bloed zweet en tranen verkregen
Typeratings: De laatste jaren in een stofzuiger ver boven het weer en het terrein. Ver weg van de avonturen die ik daarvoor heb mogen beleven en waar ik nog dagelijks aan terug denk
Uren: In verhouding met mijn leeftijd redelijk wat

Citaat:

> Origineel gepost door **Okki**
> *Ik heb vandaag ook weer een setje chemtrails over europa gelegd!*
>
> *Dat zal ze leren, die opstandige voor zichzelf denkende burgers!*

nou laten we onze eigen rol niet overdrijven... we voeren alleen uit wat onze werkgever ons opgeeft (vlieg via die&die punten naar daar en daar...) en wáár we t uitstrooien in vooraf bepaalde hoeveelheden.

Heb zelf geen idee waarom de ene dag NL, de andere dag juist Frankrijk of een ander gebied aan de beurt is.

11-04-2007, 21:58 #42

J.R.
FL 60

Airworker sinds: Jul 2003
Locatie: Bijna naast de Polderbaan
Berichten: 372
Brevet: -
Typeratings: -
Uren: -

Sorry, even een onnozele vraag:

Kan het zijn dat door jullie het KNMI het elke x bij het verkeerde eind heeft? Ik sta de laatste dagen voor de kat z'n viool, in m'n zwembroek, zonnebrilletje, cremepie etc. op het strand in Zandvoort met een hoop wit en grijs ipv blauw in de lucht?

11-04-2007, 21:28 #41

Okki
cleared FL 200

Airworker sinds: May 2001
Locatie: Nederland
Berichten: 536
Brevet: ATPL
Typeratings: Suck, Squeeze & Blow
Uren: 70 per maand

Ik heb vandaag ook weer een setje chemtrails over europa gelegd!

Dat zal ze leren, die opstandige voor zichzelf denkende burgers!

11-04-2007, 20:17 #40

Beer
Contact Houston Space Center

Airworker sinds: Dec 1999

Citaat:

> Origineel gepost door **capt. Kebab**
> *Denken jullie dat de mensen de waarheid weten achter regenbogen?*

Vast niet... vreemd overigens dat "de burger" nog nooit is opgevallen dat olie dezelfde regenboog kan produceren...

@Viper1983:

XVI.12

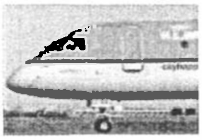
Airworker sinds: Dec 1999
Locatie: SPL
Berichten: 1.347
Brevet: JAA CPL/IR/ME (frozen ATPL)
Typeratings: Fokker 50
Uren: 1400+

Is goed, maar dan moeten we wel effe die KLM Crew laten weten dat ze nooit meer te veel moeten dumpen. Krijg je alleen geneuzel van in de Teleraaf.

Quote

11-04-2007, 20:11 #39

Eikie
Contact Houston Space Center



Airworker sinds: May 2000
Locatie: SPL
Berichten: 1.160
Brevet: ja
Typeratings: F50/E190
Uren: 2000+

Citaat:

> Origineel gepost door **capt. Kebab**
>
> *PS Als het VNV forum dicht gaat/is verwacht ik op termijn wel dat die knakkers die alles willen bekendmaken bij AB een goede kans maken op voorpaginanieuws. Heeft iemand de cleansweepers al geïnformeerd? Nu het nog kan.....*

Ik kan er weinig over los laten, maar neem van mij aan dat AB weinig op de voorpagina zal zetten over chemtrails, daar wordt (is) voor gezorgt...

Quote

11-04-2007, 20:11 #38

capt. Kebab
In orbit

Airworker sinds: Mar 2001
Locatie: Een LUXe positie
Berichten: 2.678
Brevet: opgewarmde ATPL
Typeratings: Fk50
Uren: 9211

Denken jullie dat de mensen de waarheid weten achter regenbogen?

Quote

11-04-2007, 20:06 #37

Viper1983
In orbit

Airworker sinds: Aug 2001
Locatie: NL
Berichten: 1.934
Brevet: ATPL
Typeratings: t-prop/jet
Uren: genoeg

De echte wereld...

Tja... in die ECHTE wereld bestaan chemtrails ook niet.
Helaas snappen veel mensen dat niet en blijven deze onzin verkondigen.
Laat ons dan ook eens wat onzin uit kramen

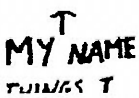
@Beer

kunnen we dat chapter over slaan?
Laten we het over chapter 8.2.4 hebben en dan het gedeelte fuel dumping in achtertuinen....

Quote

11-04-2007, 20:02 #36

Beer
Contact Houston Space Center

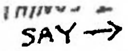


Citaat:

> Origineel gepost door **Diana**
> *Jongens, hoe vaak moet ik nog zeggen dat er nog een echte wereld daarbuiten is?*

Tja... sorry Diana. Je weet toch dat we maar een paar knoppendrukkers zijn en niet verder kunnen denken

XVI, 13



Airworker sinds: Dec 1999
Locatie: SPL
Berichten: 1.347
Brevet: JAA CPL/IR/ME (frozen ATPL)
Typeratings: Fokker 50
Uren: 1400+

dan onze volgende paycheck?

Morgen nog maar even chapter 8.2.3-11 doornemen...

Quote

#35

capt. Kebab
In orbit

Airworker sinds: Mar 2001
Locatie: Een LUXe positie
Berichten: 2.678
Brevet: opgewarmde ATPL
Typeratings: Fk50
Uren: 9211

Zo kan het ook....

De KLM heeft het iig WEL goed aangepakt met die KL736 Curacao vlucht. De media cover-up heeft daar prima gewerkt.
Van een betrouwbare bron heb ik vernomen dat de fuel/chemical ratio voor die vlucht compleet verkeerd was. In de B1 tank zat ipv kerosine een flinke hoeveelheid (zie 8.3.6.4 tweede tabel eerste goedje) jeweetwel.

En ja dan kan het goed fout gaan.

PS Als het VNV forum dicht gaat/is verwacht ik op termijn wel dat die knakkers die alles willen bekendmaken bij AB een goede kans maken op voorpaginanieuws. Heeft iemand de cleansweepers al geinformeerd? Nu het nog kan.....

Quote

#34

Diana
Administrator

Airworker sinds: Jan 1999
Locatie: Teuge
Berichten: 2.729
Brevet: PPL-A + GPL, en als ik tussen de twee zou moeten kiezen, dan werd het zonder met mijn ogen te knipperen het GPL.
Typeratings: ASK-13,21,23, SZD51, Duo Discus, LS3, LS4
Uren: 450

Jongens, hoe vaak moet ik nog zeggen dat er nog een echte wereld daarbuiten is? Je kunt hier niet alles zeggen. De betreffende pagina's noemen uit het Operations manual, daar wordt men niet vrolijk van. Ik krijg er alweer telefoon over. Hoe om te gaan met de media i.v.m. chemtrails is niet iets wat men op een publiek board terug wil zien.

Quote

#33

PH-JPC
Contact Houston Space Center

Airworker sinds: Jan 2003
Locatie: 2 rood, 2 wit, slightly right
Berichten: 1.411
Brevet: met bloed zweet en tranen verkregen
Typeratings: De laatste jaren in een stofzuiger ver boven het weer en het terrein. Ver weg van de avonturen die ik daarvoor heb mogen beleven

Hmm sinds de update van onze CCTX-software van 4 jaar terug wordt automatisch bepaald bij welke airways moet worden 'gevlogen' en in wat voor verhouding.
Die mixratio hoeven we dus gelukkig niet meer constant zelf te berekenen en bij te stellen; dat doet de EEC nu vanzelf.

Tja en die Televaag... wie gelooft die krant nou als ze zoiets plaatsen? ze doen maar

Edit: hee ik heb hetzelfde!
Probeert Diana via deze fictieve persoon wat feiten boven water te krijgen?

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en waar ik nog dagelijks aan terug denk
Uren: In verhouding met mijn leeftijd redelijk wat

Quote

1-04-2007, 16:48 #32

reach52
over to departure

Airworker sinds: Mar 2002
Locatie: 51ste verdieping
Berichten: 257
Brevet: ATPL
Typeratings: B190, E-120/170/175/190/195, B737NG, A330
Uren: liefts tussen 11:00 en 22:00 uren

Kort na het posten van bovenstaande probeerde ik het <i>public</i> profiel van Plane1 te bekijken kreeg ik de volgende boodschap:

reach52, je hebt geen toestemming voor toegang tot deze pagina. Hiervoor kunnen diverse oorzaken zijn:

1. Je gebruikersaccount heeft onvoldoende toegangsrechten voor deze pagina. Probeer je wellicht het bericht van een ander te bewerken, toegang te krijgen tot beheerdersfuncties of andere systeemtaken uit te voeren?
2. Als je probeert een bericht te posten, heeft de administrator je account mogelijk uitgeschakeld of is het account nog niet geactiveerd.

Zit airwork nu ook al in het complot?
Zouden ze weten wie ik ben?
Ben ik next to retire early?

Quote

Post Reply

Pagina 3 van 4 < 1 2 **3** 4 >

« vorig onderwerp | volgend onderwerp »

Plaatsingsregels

You **may not** post new threads
You **may not** post replies
You **may not** post attachments
You **may not** edit your posts

BB code is **Aan**
Smilies zijn **Aan**
[IMG] code is **Aan**
HTML code is **Uit**

Huisregels

Forumnavigatie
Crewroom
Ga

Alle tijden zijn UTC +2. De tijd is nu 15:31.

-- Dutch

E-mail Diana - Airwork - Archief - Naar Boven

Home Over Airwork Sitemap

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APPENDIX 17

XVIII, 1

APPENDIX 18

COPENHAGEN CONSENSUS CENTER

XVIII, 2

PRESS STATEMENT

Top Economists Recommend Climate Engineering

Copenhagen Consensus on Climate Findings: Expert Panel of Nobel Laureates Outline Best and Worst Responses to Global Warming

WASHINGTON, DC (Friday September 4, 2009) – After deliberations into the best responses to global warming, an Expert Panel of five top economists including three Nobel Laureates concluded that greater resources should be spent on research into climate engineering and green energy.

The Expert Panel's findings highlight the problems with the current political focus on carbon taxes, and underscore the vast promise shown by alternative responses to global warming.

The Expert Panel scrutinized 21 ground-breaking research papers by top climate economists that analyzed the costs and benefits of different responses to global warming, ranging from a focus on black carbon mitigation to climate engineering and varying levels of carbon taxes. Based on an analysis of the new research, they created a prioritized list (overleaf) that outlines the best and worst ways to respond to climate change.

The Expert Panel concluded that the most effective use of resources would be to invest immediately in researching marine cloud whitening technology (where boats spray seawater droplets into clouds above the sea to make them reflect more sunlight back into space, reducing warming).

Climate engineering could provide a cheap, effective and rapid response to global warming. Remarkably, research considered by the Expert Panel, written by lead author Dr Eric Bickel, suggests that a total of about $9 billion spent developing marine cloud whitening technology might be able to cancel out this entire century's global warming.

Expert Panel member and Nobel Laureate economist Thomas Schelling said, "We found that climate engineering has great promise. Even if one approaches it from a skeptical viewpoint, it is important to invest in research to identify the limitations and risks of this technology sooner rather than later."

The Expert Panel found that there is a compelling case for greater research and development into developing green energy technology. They considered a paper by economists Professor Chris Green and Isabel Galiana of McGill University showing that non-fossil energy sources will – based on today's availability—get us less than halfway toward a path of stable carbon emissions by 2050, and only a tiny fraction of the way towards stabilization by 2100. There is a need for a technology revolution, which has not yet even started.

The Expert Panel found that high carbon taxes would be an expensive, ineffective way to reduce the suffering from global warming.

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Research from Professor Richard SJ Tol showed that a high, global CO2 tax starting at $68 would reduce world GDP by a staggering 12.9% in 2100—the equivalent of $40 trillion a year – many times the expected damage of global warming.

"I hope that the Copenhagen Consensus on Climate will contribute to discussion about global warming policy by helping highlight some of the best policy responses to global warming," said Finn Kydland, Nobel Laureate in Economics "It is important to look at the most effective ways to address the climate challenge."

The Copenhagen Consensus on Climate was convened by the think-tank Copenhagen Consensus Center, whose director is Bjorn Lomborg.

"I think it's greatly encouraging that the Expert Panel has identified so many promising responses to global warming, and I hope that their findings are seriously considered by policy-makers. Their work also makes it clear that current carbon taxes and cap-and-trade policies are very poor answers to global warming. We need to re-think our priorities to best respond to this challenge," Bjorn Lomborg said.

The Expert Consensus:

RATING		SOLUTION	CATEGORY
"Very Good"	1	Marine Cloud Whitening Research	Climate Engineering
	2	Energy R&D	Technology
	3	Stratospheric Aerosol Insertion Research	Climate Engineering
	4	Carbon Storage Research	Technology
"Good"	5	Planning for Adaptation	Adaptation
	6	Research into Air Capture	Climate Engineering
"Fair"	7	Technology Transfers	Technology Transfers
	8	Expand and Protect Forests	Forestry
	9	Stoves in Developing Nations	Cut Black Carbon
"Poor"	10	Methane Reduction Portfolio	Cut Methane
	11	Diesel Vehicle Emissions	Cut Black Carbon
	12	$20 OECD Carbon Tax	Cut Carbon
"Very Poor"	13	$0.50 Global CO_2 Tax	Cut Carbon
	14	$3 Global CO_2 Tax	Cut Carbon
	15	$68 Global CO_2 Tax	Cut Carbon

Interviews

COPENHAGEN CONSENSUS CENTER

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Bjorn Lomborg and Expert Panel member Finn Kydland are available in Washington DC and New York for interviews, September 3 and 4.

Press contacts:

- David Young (in Washington DC) +45 27 82 0644 or dy.ccc@cbs.dk
- Anita Overholt Nielsen (in Copenhagen) +45 22 78 38 75 or aon.ccc@cbs.dk

COPENHAGEN CONSENSUS CENTER

Background Information

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What the New Research Examined

The groundbreaking research papers look at the following eight topics:

Climate Engineering • Carbon Mitigation • Forestry • Black Carbon Mitigation •Methane Mitigation •Adaptation • Research and Development • Technology Transfers

All of the research is available at www.fixtheclimate.com

The Expert Panel

The Expert Panel that gathered at Georgetown University to consider the research comprised:

- Finn E Kydland, Nobel Laureate
- Thomas C Schelling, Nobel Laureate
- Vernon L Smith, Nobel Laureate
- Nancy L Stokey, Frederick Henry Prince Distinguished Service Professor of Economics at the University of Chicago
- Jagdish Bhagwati, University Professor at Columbia University

Copenhagen Consensus Center

The Copenhagen Consensus Center is a think-tank based in Denmark that informs governments, philanthropists and the public about the best ways to spend aid and development money. The Center commissions research that identifies the best spending priorities in any given area. The Center promotes the use of fact-based economic science – especially the principle of prioritization – to make sure that with limited resources, we achieve the most 'good' for people and the planet.

Bjorn Lomborg, Director, Copenhagen Consensus Center

Bjorn Lomborg, the director of the Copenhagen Consensus Center, is a global opinion leader. He is the author of ***Cool It*** and ***The Skeptical Environmentalist***. He was named one of the 75 most influential people of the 21st Century by *Esquire* magazine, one of the 50 people who could save the planet by the *Guardian*, one of the top

100 public intellectuals by *Foreign Policy*, and one of the world's 100 most influential people by *Time*. He is the former director of Denmark's Environmental Assessment Institute, and an adjunct professor at Copenhagen Business School.

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APPENDIX 19

IOP | electronic journals

Environmental Research Letters
The open-access journal for environmental science

Journals Home | Journals List | EJs Extra | This Journal | Search | Authors | Referees | Librarians | User Options | Help

This volume | This issue | Abstract | Content finder
Environ. Res. Lett. 4 (October-December 2009) 045102
doi:10.1088/1748-9326/4/4/045102

XIX, 2

Modification of cirrus clouds to reduce global warming

David L Mitchell and William Finnegan

Desert Research Institute, Reno, NV 89512-1095, USA

E-mail: david.mitchell@dri.edu

Received 1 April 2009
Accepted 12 August 2009
Published 30 October 2009

Abstract. Greenhouse gases and cirrus clouds regulate outgoing longwave radiation (OLR) and cirrus cloud coverage is predicted to be sensitive to the ice fall speed which depends on ice crystal size. The higher the cirrus, the greater their impact is on OLR. Thus by changing ice crystal size in the coldest cirrus, OLR and climate might be modified. Fortunately the coldest cirrus have the highest ice supersaturation due to the dominance of homogeneous freezing nucleation. Seeding such cirrus with very efficient heterogeneous ice nuclei should produce larger ice crystals due to vapor competition effects, thus increasing OLR and surface cooling. Preliminary estimates of this global net cloud forcing are more negative than –2.8 W m^{-2} and could neutralize the radiative forcing due to a CO_2 doubling (3.7 W m^{-2}). A potential delivery mechanism for the seeding material is already in place: the airline industry. Since seeding aerosol residence times in the troposphere are relatively short, the climate might return to its normal state within months after stopping the geoengineering experiment. The main known drawback to this approach is that it would not stop ocean acidification. It does not have many of the drawbacks that stratospheric injection of sulfur species has.

Keywords: geoengineering, cirrus clouds, climate modeling

Contents

- 1. Introduction
- 2. Geoengineering idea
  - 2.1. Potential seeding material
  - 2.2. Delivery mechanism
  - 2.3. Production of new cirrus
- 3. Evidence from GCM studies
- 4. Advantages and drawbacks
- 5. Next steps?
- 6. Recapitulation
- Acknowledgments
- References

1. Introduction

Geoengineering ideas have been classified into two categories (Lenton and Vaughan 2009): (1) those increasing reflectance of solar radiation and (2) those increasing outgoing longwave radiation (OLR) by removing greenhouse gases like carbon dioxide. The geoengineering idea proposed in this letter fits in neither of these categories, although it would if category 2 were broadened by removing the restriction of greenhouse gas removal. The idea proposed is to cool surface temperatures by reducing the coverage of high cirrus clouds to increase OLR.

Since greenhouse gases warm the planet by trapping OLR, and clouds have the greatest impact on the earth radiation budget, it may make sense to target clouds that most strongly regulate OLR for climate engineering purposes. Of the nine cloud types considered in Chen *et al* (2000), cirrus clouds (visible optical depth < 3.6, cloud top pressure < 440 mb) had the greatest impact on top-of-atmosphere (TOA) longwave fluxes and had a global annual mean net warming of + 1.3 W m^{-2}. A similar study (Hartmann *et al* 1992) found a TOA global annual net cloud forcing for cirrus (optical depth < 9.4) of + 2.4 W m^{-2}. Thus cirrus tend to trap more outgoing thermal radiation than they reflect incoming solar radiation and have an overall warming effect on the climate system. Conversely, liquid water clouds have a net cooling effect, reflecting more solar radiation than retention of longwave radiation. This difference is primarily due to the relatively cold temperatures of cirrus clouds, causing the earth to

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radiate at an effectively colder temperature (i.e. nearer the cirrus cloud temperature), thus trapping thermal radiation below cirrus altitudes that would otherwise escape to space. This is why the higher (i.e. colder) the cirrus clouds are, the greater is their OLR impact. Both liquid water and cirrus clouds effectively absorb and emit longwave radiation, but the low water clouds are emitting this thermal radiation at temperatures only slightly cooler than the surface. Thus it makes sense to target the colder cirrus clouds for geoengineering due to their greater impact on OLR.

One approach for selecting a geoengineering strategy is to target a component of the climate system that the climate system is sensitive to and can be intentionally modified. Recent research indicates that cirrus microphysics has a strong impact on climate sensitivity, S (i.e. the equilibrium response of global mean surface temperature to CO_2 doubling). In the recent study by Sanderson *et al* (2008), an ensemble of thousands of 'perturbed physics' global climate model (GCM) simulations was provided through the distributed computing project, climate*prediction*.net. A principle component analysis was applied to identify the dominant physical processes responsible for variation in S across the ensemble. The two leading EOFs accounted for 70% of the ensemble variance in λ—the global feedback parameter, where $\lambda = 1/S$. Both EOFs were dominated strongly by one physical parameter; the entrainment coefficient for the first EOF and the ice fall speed for the second EOF. The entrainment coefficient controls the amount of moisture laden boundary layer air that is vertically advected into the upper troposphere in thunderstorms (i.e. a coefficient of zero means no dilution of boundary layer air upon ascent). The ice fall speed controls ice removal rates from cirrus, thus affecting the cirrus ice water path (IWP), life cycle and coverage. Both parameters govern λ by affecting (1) the cirrus coverage and IWP and (2) the upper troposphere relative humidity. The main impact of reducing the entrainment coefficient was an enhanced clear-sky greenhouse effect, while the main impact of reducing the ice fall speed was an increase in longwave cloud forcing. In regards to cloud forcing, this study indicates that climate sensitivity depends more on changes in cirrus clouds than on low-level boundary layer clouds.

Another GCM study by Mitchell *et al* (2008) relates the findings in Sanderson *et al* (2008) more intimately to cirrus microphysics by relating the ice particle mass, area, and ice particle size distribution (PSD) to the ice fall speed and optical properties. It was shown that changing the concentrations of small ice crystals (i.e. the degree of bimodality) of the PSD strongly affects the representative PSD ice fall speed, V_t. By increasing V_t, the cirrus IWP decreased by 12% and cirrus coverage decreased by 5.5% globally. This substantially affected annual global means of cloud forcing, heating rates and temperatures in the upper troposphere.

The Sanderson *et al* and Mitchell *et al* studies combined indicate that climate sensitivity depends substantially on the ice fall speed and that the ice fall speed depends on ice nucleation rates (i.e. the concentrations of small ice crystals). Therefore a successful geoengineering strategy might be to modify the ice fall speed by modifying ice nucleation rates.

2. Geoengineering idea

The essence of this idea was described under conclusions in Mitchell *et al* (2008). The idea relates to the interaction between homogeneous and heterogeneous ice nucleation in cirrus clouds, which has been recently the focus of much research. The main distinction here is the linking of this topic to the ice fall speed (which was also done by Lohmann *et al* 2008) and the application to the field of geoengineering.

An important process for ice crystal production in cirrus clouds is homogeneous freezing nucleation, which seems fairly well understood (Sassen and Dodd 1988, Heymsfield and Sabin 1989, Koop *et al* 2000, DeMott 2002, Lin *et al* 2002, Mohler *et al* 2003, Haag *et al* 2003a, Koop 2004). At temperatures below −37 °C, homogeneous freezing nucleation on haze droplets often prevails and ice supersaturations (S_i) are relatively high (e.g. ~ 45–60%) in cirrus clouds. Heterogeneous ice nucleation generally occurs at lower S_i and insoluble aerosol particles that nucleate ice crystals in this way can out-compete the homogeneous freezing ice nuclei for water vapor. Heterogeneous ice nuclei include crystal or mineral particles (e.g. Zuberi *et al* 2002, DeMott *et al* 2003a, Richardson *et al* 2007) and some types of soot (e.g. Kärcher 1996, Jensen and Toon 1997, DeMott *et al* 1997, Karcher *et al* 2007). Homogeneous freezing nucleation is thought to dominate ice crystal production at temperatures less than −40 °C (Karcher and Spichtinger 2009), consistent with the higher S_i observed in this temperature regime (e.g. Ström *et al* 2003). If so, then the introduction of very efficient heterogeneous ice nuclei at these cold temperatures in the right concentration may result in larger ice crystals as the heterogeneous ice nuclei would out-compete the homogeneous freezing nuclei. This process has been coined as the negative Twomey effect (Karcher and Lohmann 2003) in association with the traditional Twomey effect in liquid water clouds, where increases in cloud condensation nuclei produce higher cloud droplet concentrations and cloud albedo. The negative Twomey effect can lead to reductions in ice particle concentration by up to a factor of 10 under natural conditions and to decreased cirrus cloud albedo (Haag and Kärcher 2004). Indirect observational evidence for a negative Twomey effect is described in a satellite study of ice cloud–aerosol interactions over the Indian Ocean (Chylek *et al* 2006) while *in situ* measurements have provided direct evidence (Haag *et al* 2003b, DeMott *et al* 2003b).

Substances exist that nucleate ice crystals as effectively as silver iodide (Agl, the best ice nucleant known) at cirrus cloud temperatures, and some are relatively inexpensive and non-toxic (see section 2.1). If significantly larger, these artificially seeded ice crystals would fall faster, and their higher fall velocities may lead to reduced cirrus cloud coverage as predicted in GCM simulations (Mitchell *et al* 2008, Sanderson *et al* 2008). The lower cirrus cloud coverage would result in greater OLR and cooler surface temperatures, thus reducing the impact of global warming. It is important to note that the decrease in cirrus coverage would occur where the cirrus greenhouse effect is strongest (i.e. temperatures < −40 °C). This is a key principle for this geoengineering idea.

Soot particles emitted from aircraft jet engines may possibly nucleate ice through heterogeneous nucleation (e.g. Mohler *et al* 2005b), but soot particles may also become coated with soluble species that make them act more like homogeneous freezing nuclei (Möhler *et al* 2005b, 2005a, DeMott *et al* 1999). Other studies have found that jet fuel exhaust particles fail to nucleate ice below water saturation (DeMott *et al* 2002), and that fresh biomass combustion particles act as homogeneous freezing ice

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nuclei (DeMott *et al* 2009). Thus many have argued that the evidence implicating soot particles as heterogeneous ice nuclei in the upper troposphere is rather poor. Moreover, even when considered as a heterogeneous ice nucleus, an ice supersaturation threshold of ~ 30% is often assumed for soot (e.g. Karcher *et al* 2007). In this case one would expect efficient ice crystal seeding material introduced into the upper troposphere to generally out-compete soot particles for water vapor.

A modeling study by Karcher *et al* (2007) describes the vapor competition between crustal aerosol, soot and homogeneous freezing ice nuclei, where the latter were sulfuric acid particles at 500 cm^{-3}. We first consider the case when soot is ignored and vapor competition is only between homogeneous freezing nuclei and crustal aerosol (i.e. dust), with a critical S_i for dust nucleation of 10% and 55% for homogeneous freezing. Mineral dust particles can be viewed as a surrogate here for the geoengineered seeding material. For cloud updrafts of 5 and 25 cm s^{-1} with dust concentrations of 2 and 20 l^{-1}, respectively, ice crystal number concentrations were reduced by a factor of 5 by the introduction of the dust aerosol. If we assume an ice particle mass–dimension relationship of the form $m = \alpha D^{\beta}$, where $\beta = 2.8$ for dimension $D < 240$ μm (Mitchell *et al* 2009), then it can be shown that a five-fold reduction in ice crystal concentration results in an increase in D by a factor of 1.8. If we assume that the ice fall speed (representing the PSD downward mass flux) lies in the range 15–50 cm s^{-1} for $T < -40$ °C, an 80% increase in ice crystal length would increase the fall velocity by ~ 70–130% (Mitchell and Heymsfield 2005). Such an increase would significantly change cirrus cloud coverage. Introducing soot with a S_i threshold between 30% and 50% does not seriously change these results until the soot concentration exceeds ~ 2 l^{-1} for the 5 cm s^{-1} updraft and 20 l^{-1} for the 25 cm s^{-1} updraft. Higher soot concentrations increase ice crystal concentrations, which then become less sensitive to nuclei type. Thus, if ambient soot particles do serve as ice nuclei and their concentrations are sufficiently high, it is possible that they would inhibit or prevent the seeded ice crystals from growing large enough to have sufficiently high fall velocities needed to significantly reduce cirrus cloud cover.

2.1. Potential seeding material

An ideal ice nucleating agent for cirrus geoengineering would be one having a high effectivity (for ice nucleation) at temperatures colder than ~ –20 °C, but a very low effectivity at warmer temperatures. Bismuth tri-iodide (BiI_3) had been investigated as an ice nucleant for weather modification programs but was unsuitable because its effectivity threshold was below –10 °C. However, this makes it a suitable ice nucleant for geoengineering, targeting primarily cirrus clouds and not the clouds normally targeted in cloud seeding experiments. In addition, BiI_3 is non-toxic and reagent grade bismuth metal is about 1/12th the cost of silver, suggesting BiI_3 would be about 1/12th the cost of AgI.

Bismuth tri-iodide can be generated in aerosol form by combustion of an alcohol solution of BiI_3 (solubility, 3.5 g/100 ml). A better aerosol generating system for this nucleant is pyrotechnic combustion. For this, a modest program of research and development would be required. A pressed composite mixture of BiI_3, potassium perchlorate ($KClO_4$), aluminum and gilsonite (a natural hydrocarbon) would be appropriate.

2.2. Delivery mechanism

Since commercial airliners routinely fly in the region where cold cirrus clouds exist, it is hoped that the seeding material could either be (1) dissolved or suspended in their jet fuel and later burned with the fuel to create seeding aerosol, or (2) injected into the hot engine exhaust, which should vaporize the seeding material, allowing it to condense as aerosol in the jet contrail. The objective would not be to seed specific cloud systems but rather to build up a background concentration of aerosol seeding material so that the air masses that cirrus will form in will contain the appropriate amount of seeding material to produce larger ice crystals. Since the residence time of seeding material might be on the order of 1–2 weeks, release rates of seeding material would need to account for this. With the delivery process already existing, this geoengineering approach may be less expensive than other proposed approaches.

2.3. Production of new cirrus

Aircraft (Helten *et al* 1998, Spichtinger *et al* 2004) and microwave limb sounder (MLS) satellite measurements (Read *et al* 2001, Spichtinger *et al* 2003) show that large portions of the clear-sky upper troposphere are supersaturated with respect to ice. While natural cirrus may or may not form in these regions over time, the global, quasi-uniform distribution and continuous introduction of efficient heterogeneous ice nuclei might produce more cirrus clouds in these regions than would otherwise occur. Over time, the relatively large ice crystals would sediment to lower levels and warmer temperatures where the cirrus greenhouse effect is less. Water vapor concentrations in the upper troposphere should decrease with this export of moisture to lower levels, and the water vapor greenhouse effect in the upper troposphere should decrease. In fact, the upper troposphere water vapor content in GCMs (affecting the clear-sky OLR) is sometimes 'tuned' by changing the ice fall speed.

The impact of the ice fall speed on global relative humidity (RH) is shown in figure 1, based on the GCM study described in Mitchell *et al* (2008). By increasing the ice fall speed primarily for cold ($T < -40$ °C) cirrus, RH is significantly decreased, which increases the clear-sky OLR.

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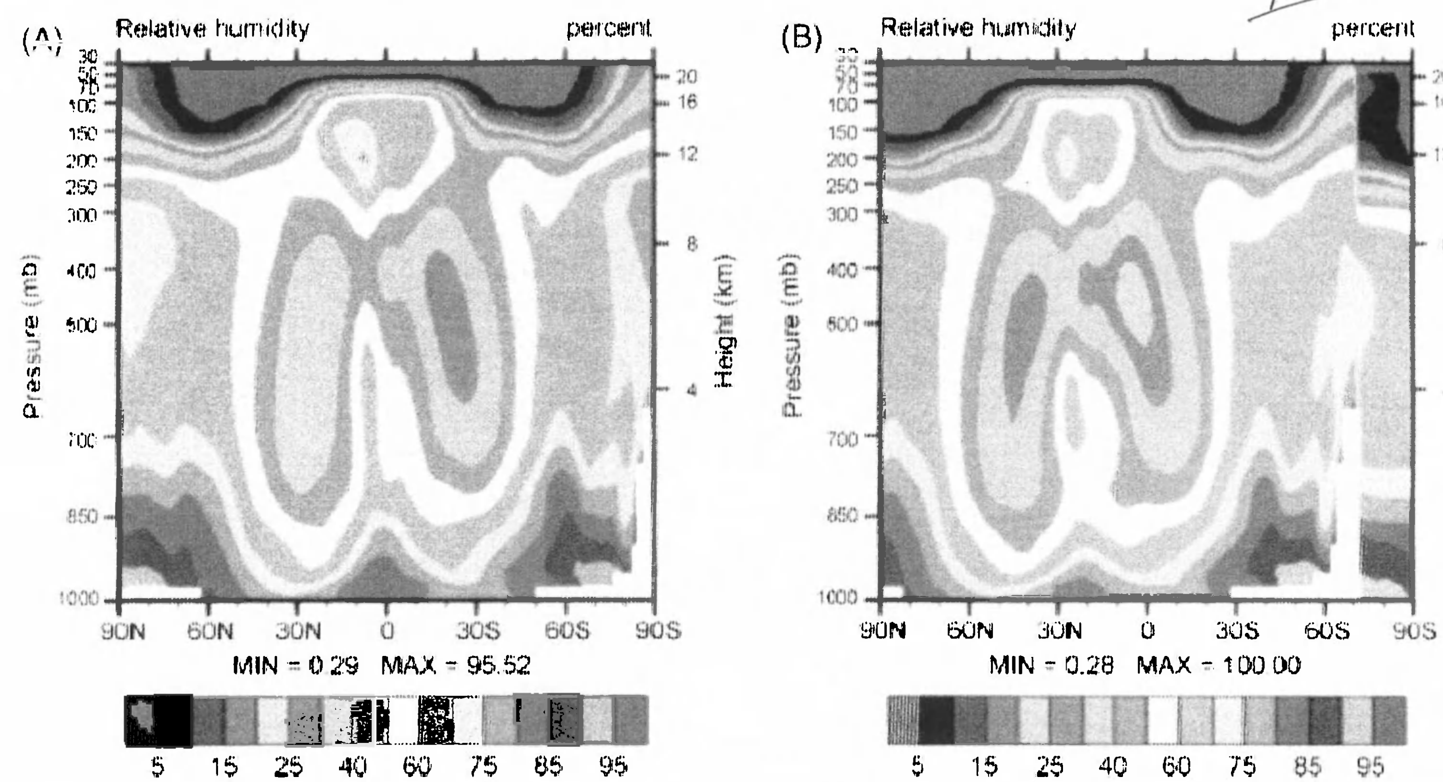

Figure 1. (A) Lower ice fall speed simulation in Mitchell *et al* (2008), showing relatively higher RH in the upper and middle troposphere. (B) Corresponding higher ice fall speed simulation from Mitchell *et al* (2008). A plotting offset error occurred (~ 18°) in extreme right side of image.

Therefore the equilibrium response to the global introduction of sufficient concentrations of efficient ice nuclei may be a drier upper troposphere having less cirrus coverage. This could substantially increase the amount of outgoing longwave radiation (OLR) and thus have a substantial cooling effect on surface temperatures.

3. Evidence from GCM studies

Some insight into the theoretical plausibility of this geoengineering idea can be obtained from GCM studies investigating the influence of homogeneous and heterogeneous ice nucleation on climate. Such a study was conducted by Lohmann *et al* (2008) using the ECHAM5 GCM, which contains a two-moment cloud microphysics and two-moment aerosol microphysics scheme, and thus can form cirrus either by homogeneous or heterogeneous freezing. Homogeneous freezing was permitted on soluble/mixed Aitken, accumulation and coarse mode aerosol, while heterogeneous freezing nuclei were comprised of immersed mineral dust that froze at 30% S_i. A number of simulations were performed, including (1) homogeneous freezing only, where solution droplets (that limit homogeneous freezing) often exceeded 100 cm^{-3} at cirrus levels; (2) heterogeneous freezing of mineral dust (~ 0.02–0.2 cm^{-3} at cirrus levels) when S_i exceeds 30%; (3) both homogeneous and heterogeneous freezing are allowed such that only heterogeneous freezing occurs when the immersion dust nuclei concentration exceeds 1 l^{-1}, and homogeneous freezing occurs otherwise. This was justified since both nucleation mechanisms seldom occur simultaneously. Henceforth these three simulations will be referred to as E5-homo, E5-het and E5-homhet, respectively.

This version of ECHAM5 included improved ice microphysics, with a more realistic treatment of ice particle fall velocities that depend on ice crystal shape and mass, with quasi-spherical 'droxtals' assumed at small sizes and columnar crystals otherwise. Relating the ice particle size and mass to the fall velocity, as done here, is critical for exploring this geoengineering idea.

Some results from this study are shown above in figure 2, showing annual zonal means for the cirrus PSD effective radius r_e, cirrus cloud coverage, and shortwave and longwave cloud forcing for each of the ECHAM5 simulations mentioned above along with observational data. Ice crystal concentrations (not shown) in E5-homo were 50% greater on average relative to E5-het and E5-homhet, resulting in a global annual mean r_e of 29.7 μm for E5-homo and a corresponding r_e of 32.7 and 33.0 μm for E5-het and E5-homhet, respectively. As expected, the heterogeneous ice nuclei in simulations E5-het and E5-homhet, activating at lower S_i, produce larger ice crystals with higher fall velocities, resulting in less cloud coverage. The shortwave cloud forcing for E5-homo is only slightly stronger than E5-het and E5-homhet, while the longwave cloud forcing is significantly greater for E5-homo than E5-het or E5-homhet. This derives from the fact that cirrus coverage and IWP were decreased for the coldest cirrus in E5-het and E5-homhet. The global annual means for shortwave and longwave cloud forcing were reduced in E5-het and E5-homhet by 2.7 W m^{-2} and 4.7 W m^{-2}, respectively, relative to E5-homo, giving a net global cirrus cloud forcing of 2.0 W m^{-2}, with the OLR increase exceeding the cloud reflectance decrease by 2.0 W m^{-2}. While not reported in Lohmann *et al* (2008), the global mean change in net TOA radiation for the het–homo and homhet–homo comparisons was –2.8 W m^{-2} and –2.5 W m^{-2}, respectively, with the additional cooling due to a change in the clear-sky fluxes (resulting from a decrease in RH in the het and homhet simulations) (Lohmann 2009). These results suggest that the above geoengineering strategy could be effective for

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slowing the rate of global warming since the forcing due to a doubling of atmospheric CO_2 is estimated to be 3.71 W m^{-2} (Lenton and Vaughan 2009).

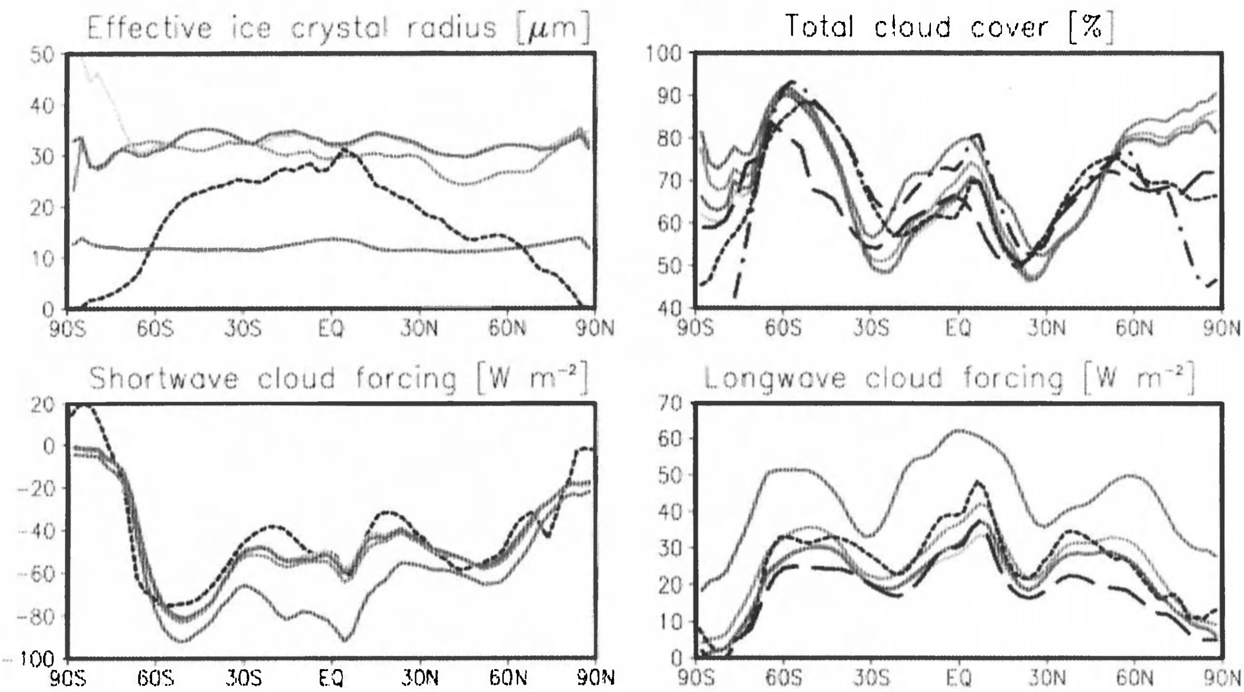

Figure 2. Annual zonal means for ECHAM5 simulations E5-homo (red), E5-het (green), E5-homhet (blue), and for water vapor accommodation coefficient = 0.006 (purple). Black dashed curves show observational data. As indicated, the zonal means show the cirrus PSD effective radius (μm), total cirrus cloud cover (%), and shortwave and longwave cloud forcing (W m^{-2}). From Lohmann *et al* (2008).

If the Lohmann *et al* (2008) study predicts a net global cooling of ~ 2.7 W m^{-2} from increasing ice particle sizes by only 11%, where S_i for heterogeneous freezing is 30%, it would be interesting to determine what change in ice crystal size is likely for very efficient heterogeneous ice nuclei, where $S_i \approx$ 1–5%. Clearly a larger size increase should produce a larger increase in fall velocity and a larger decrease in cloud cover and a larger net cooling.

Supporting results were obtained in Mitchell *et al* (2008), where the ice particle mass, area, and the PSD were related to the ice fall speed and optical properties in the Community Atmosphere Model version 3 (CAM3). The fall speed representing the PSD mass flux was altered by changing the relative concentrations of small ice crystals, with one CAM3 simulation having lower fall speeds than the other simulation. The higher fall speed simulation had 5.5% less cirrus cloud coverage. As shown in figure 3, the shortwave cloud forcing in the midlatitude and polar regions was almost unchanged since low clouds dominate shortwave cloud forcing there, but the longwave cloud forcing difference was appreciable since it depends mostly on high clouds. These simulations suggest cirrus seeding may be most effective in the polar and midlatitude regions where global warming is more severe.

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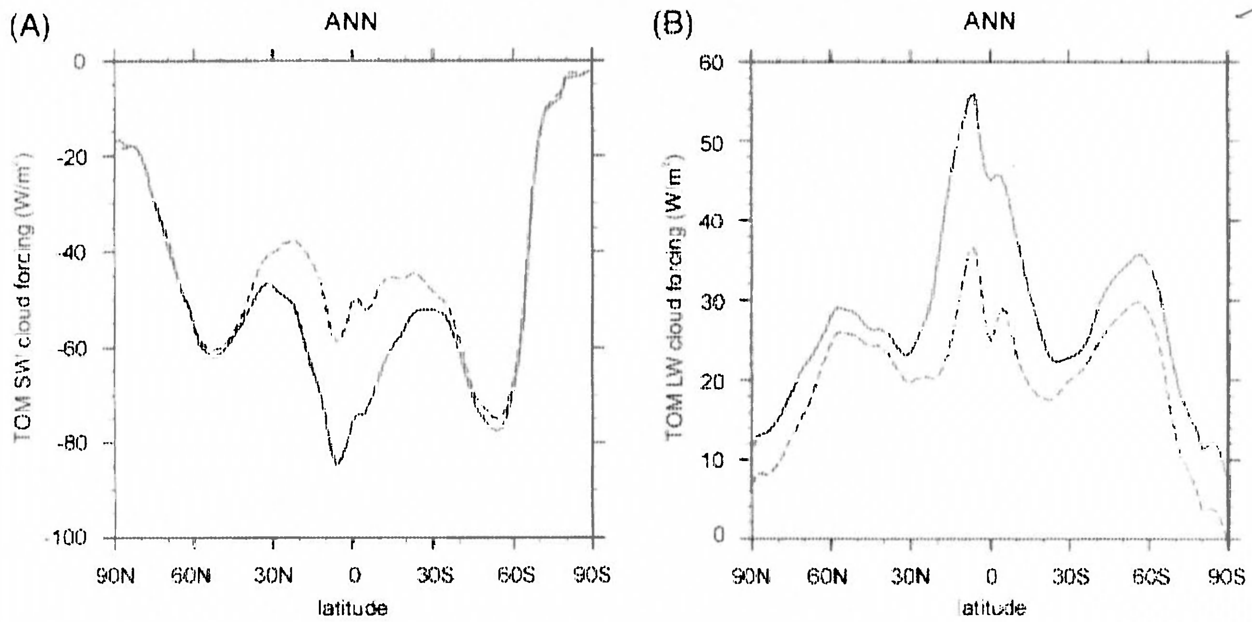

Figure 3. (A) Annual zonal mean shortwave cloud forcing in the higher ice fall speed (blue dashed) and lower ice fall speed (red solid) CAM3 simulations. (B) Same but for longwave cloud forcing. From Mitchell *et al* (2008). TOM = top of model atmosphere.

It should be noted that for the two simulations in Mitchell *et al* (2008), the difference in the ice fall speed is manifested primarily for temperatures < -45 °C. This is the region most targeted in this geoengineering scheme, and is the region where the greenhouse effect of cirrus clouds is most powerful.

4. Advantages and drawbacks

A review of possible geoengineering approaches is given in Lenton and Vaughan (2009), and of the many listed, only two, stratospheric injection of sulfate aerosols and mechanical seeding of marine stratus clouds, seemed capable of fully neutralizing the radiative forcing due to a doubling of CO_2. The exploratory investigation described here indicates that cirrus cloud seeding is also having the potential to fully neutralize the radiative forcing from a CO_2 doubling. In addition, this approach could be relatively inexpensive if a method were developed to disperse the seeding material from commercial aircraft and the commercial airline industries were willing partners. The details of what would be the ideal ambient concentration of seeding material and how much seeding material would be needed to realize this concentration have not yet been worked out.

As described under section 1, recent GCM studies suggest that cirrus clouds and upper tropospheric water vapor represent the component of the climate system that most strongly affects the prediction of climate sensitivity. Thus it seems logical to target this component in a geoengineering strategy. Moreover, greenhouse gases trap OLR, and cirrus affect OLR more than all other cloud types (Chen *et al* 2000, Hartmann *et al* 1992). In this way this strategy directly addresses the radiation imbalance due to greenhouse gases.

The most studied geoengineering option, stratospheric injection of sulfate aerosols, has some drawbacks, such as (1) increasing the rates of stratospheric ozone destruction, (2) higher costs of injecting sulfur compounds into the stratosphere, (3) decreased solar radiation possibly altering the hydrological cycle with more frequent droughts (Trenberth and Dai 2007), (4) change in sky color from blue to white and (5) less solar power. In addition, modeling studies indicate it would take at least 3 years for the climate system to return to 'normal' upon termination of this geoengineering. The cirrus seeding option does not appear to suffer from these drawbacks, although slightly more solar radiation would reach the surface with less cirrus cloud coverage. Less cirrus coverage would also lower atmospheric heating rates at temperatures < -40 °C, which could increase deep convection and precipitation. Since the residence time of cloud seeding aerosols is on the order of 1–2 weeks, the cirrus seeding option could easily be terminated if unanticipated environmental problems arose from this practice. None of the 'albedo' geoengineering options address the problem of ocean acidification due to elevated CO_2 concentrations, and this is true for the cirrus seeding option as well.

Instead of seeding cirrus throughout the world, an alternate option is to seed cirrus mostly over the polar regions and midlatitudes, since these are the regions most affected by global warming. The density of airline flight corridors is highest over these regions and least dense over the tropics, so a seeding strategy based on commercial airline flights might naturally favor this prioritization. Such a strategy might affect OLR in these regions by a greater percentage than the tropics. One potential drawback or advantage to this approach, depending on how you look at it, would be a possible increase in the temperature gradient between the polar and tropical air masses. This intensification of the global temperature gradients should lead to stronger jet streams with greater baroclinicity, with stronger and more frequent storms along the storm track (Wallace and Hobbs 1977). In a warmer climate, the jet streams might shift polewards and midlatitude weather systems might become weaker (Yin 2005, Bengtsson *et al* 2006). If correct, this geoengineering strategy might counteract this to some degree and alleviate global warming induced drought in some regions. On the other hand, an intensified storm track could increase cloud cover at all levels, and the complex implications of such a proposal would need to be investigated through GCM studies.

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One potential drawback is the seeding material itself; it must be non-toxic and not too expensive. As noted, there do appear to be substances available that meet these criteria. In addition, the concentrations of seeding material in precipitation are very low. Cloud seeding studies using AgI show that the levels of AgI in seeded snowfall are generally less than 10 ppt, which does not pose any risk to human health (Super 1986, Warburton *et al* 1995).

Another geoengineering idea targeting cirrus clouds has been proposed by Cotton (2009). That idea suggests increasing the amount of soot in the upper troposphere to increase temperatures there to reduce cirrus coverage through sublimation. The solar radiation absorbed by soot would decrease temperatures at the surface, and the reduced cirrus coverage would allow more OLR to escape. However, the higher temperatures produced by soot may not change the RH (Held and Soden 2000), making the fate of cirrus less certain. Details describing the efficacy of this approach have not yet been released.

Perhaps the greatest drawback to this and any other geoengineering option is that it may divert political will and resources away from mitigation strategies designed to reduce the levels of greenhouse gases. It is argued that it would be a mistake to view geoengineering as a remedy for global warming since if the level of greenhouse gases are not reduced, the non-engineered climate will become increasingly hostile to human life on Earth. Mankind would become increasingly dependent on geoengineering, which can only neutralize greenhouse gas warming for a limited amount of time before increasing greenhouse gas levels overwhelm the radiative forcing due to geoengineering. At that `moment of truth' a planetary climate holocaust would result. Therefore, geoengineering should be viewed as a means to `buy time' for the implementation of `green' energy technologies and to allow greenhouse gas mitigation strategies time to work. At the same time, climate catastrophes that might otherwise occur might be avoided.

5. Next steps?

More detailed modeling studies of cirrus microphysics, testing some of the physical principles and assumptions used here, as well as related laboratory studies, should be carried out. For example, in cirrus generated from mesoscale motions, their microphysical properties appear to be governed by the dynamics (Karcher and Strom 2003). Modeling studies could be conducted to examine how significant the negative Twomey effect is in these cirrus. Another uncertainty is the ice sedimentation rate, a key factor determining how strong an effect this climate engineering approach is likely to have. The rate of increase in the ice particle fall velocity with respect to particle size, $\mathrm{d}V/\mathrm{d}D$ where D = ice particle maximum dimension, decreases with increasing D. Hence this approach will be most effective for narrow PSD where the relative change in size after seeding is large. *In situ* measurements indicate such PSD are common when $T < -40$ °C, but these measurements may be contaminated by larger ice particles shattering at the inlet of the measurement probe, producing many small artifact ice fragments that are counted as natural ice crystals. This problem of ice particle shattering has cast a cloud of uncertainty over *in situ* PSD measurements and needs to be resolved to obtain reliable estimates of ice sedimentation rates, which depend strongly on the concentrations of small ice crystals (Mitchell *et al* 2008).

Drawing from these process-oriented studies, GCM experiments could be designed to test this hypothesis. Since the parameterized physics differs considerably between GCMs, climate predictions differ as well, making it important to test this hypothesis in more than one GCM. In all GCM experiments, ice particle size, mass and projected area must be represented as accurately as possible for reliable fall speed estimates, and the cirrus microphysics should be coupled with the cirrus optical properties (Mitchell *et al* 2008, Baran 2009).

Field experiments could also be designed to test certain aspects of the hypothesis, such as the impact of efficient ice nuclei on the microphysics of cold cirrus wave clouds (i.e. upwind seeding of only one section of cloud and comparing the microphysics of seeded and unseeded sections). Such field studies could benefit from complementary satellite and ground based remote sensing studies, as considerable microphysical information can now be obtained through remote sensing. If such studies supported the hypothesis, the idea could be implemented by injecting cloud seeding material into the exhaust of commercial airliners that normally fly in this temperature regime (without involving the jet engines themselves).

6. Recapitulation

Recent GCM studies (Sanderson *et al* 2008, Mitchell *et al* 2008) suggest that climate sensitivity is very sensitive to upper tropospheric cloud cover and humidity, making cirrus clouds a logical candidate for climate modification efforts. Cirrus clouds also affect OLR more than other cloud types, with their modification directly addressing the radiation imbalance imposed by greenhouse gases. Due to the expected dominance of homogeneous freezing nucleation at temperatures below −40 °C, it may be possible to decrease cirrus cloud coverage by introducing efficient heterogeneous ice nuclei at these temperatures where the cirrus greenhouse effect is strongest. Due to vapor competition effects, this may result in larger ice crystals with higher fall velocities, which should decrease cirrus coverage and increase OLR, thus cooling surface temperatures. While there may be an initial increase in cirrus coverage due to ice supersaturation in clear skies, over time the increase in net downward transport of water substance (due to higher ice fall speeds) should reduce the relative humidity and cirrus coverage of the upper troposphere. Based on one GCM study, it appears that seeding cirrus clouds on a global scale could cool the planet by well more than 2.8 W m^{-2}, perhaps enough to cancel the radiative forcing due to a doubling of CO_2 (3.7 W m^{-2}). The distribution of seeding material could be done relatively inexpensively through the airline industry. Seeding along conventional flight corridors should increase OLR preferentially over the northern high latitudes where global warming is most severe. But this may also slightly intensify the global temperature gradients, the jet streams and the frequency and strength of frontal systems. Studies employing a variety of GCMs might be needed to understand the feedbacks involved. On the other hand, this geoengineering option does not have many of the drawbacks that the most studied geoengineering option has, that option being the stratospheric injection of sulfur compounds.

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References

Baran A J 2009 *J. Quantum Spectrosc. Radiat. Trans.* **110** 1579–98
CrossRef Link | Order from Infotrieve
Bengtsson L, Hodges K I and Roeckner E 2006 *J. Clim.* **19** 3518–43
CrossRef Link | Order from Infotrieve
Chen T, Rossow W and Zhang Y 2000 *J. Clim.* **13** 264–86
CrossRef Link | Order from Infotrieve
Cotton W R 2009 *Clouds in the Perturbed Climate System* ed J Heintzenberg and R J Charlson (Cambridge, MA: MIT Press) p 597
Chylek P *et al* 2006 *Geophys. Res. Lett.* **33** L06806
CrossRef Link | Order from Infotrieve
DeMott P J 2002 *Cirrus* ed D K Lynch*et al* (New York: Oxford University Press) pp 102–35
DeMott P J, Chen Y and Kreidenweis S M 1999 *Geophys. Res. Lett.* **26** 2429–32
CrossRef Link | Order from Infotrieve
DeMott P J, Petters M D, Prenni A J, Carrico C M and Kreidenweis S M 2009 *Atmos. Chem. Phys.* submitted
DeMott P J, Prenni A J, Archuleta C A and Kreidenweis S A 2002 *AMS Conf. on Cloud Physics (Ogden, UT, June 2002)* on CM-ROM
DeMott P J, Rogers D C and Kreidenweis S M 1997 *J. Geophys. Res.* **102** 19575–84
CrossRef Link | Order from Infotrieve
DeMott P J, Sassen K, Poellot M, Baumgardner D, Rogers D C, Brooks S, Prenni A J and Kreidenweis S M 2003a *Geophys. Res. Lett.* **30** 1732
CrossRef Link | Order from Infotrieve
DeMott P J *et al* 2003b *Proc. Natl Acad. Sci.* **100** 14655–60
CrossRef Link | PubMed Abstract | Order from Infotrieve
Haag W and Karcher B 2004 *J. Geophys. Res.* **109** D12202
CrossRef Link | Order from Infotrieve
Haag W, Karcher B, Schaefers S, Stetzer O, Mohler O, Schurath U, Kramer M and Schiller C 2003a *Atmos. Chem. Phys.* **3** 195–210
Order from Infotrieve
Haag W *et al* 2003b *Atmos. Chem. Phys.* **3** 1791–806
Order from Infotrieve
Hartmann D, Ockert-Bell M and Michelsen M 1992 *J. Clim.* **5** 1281–304
CrossRef Link | Order from Infotrieve
Held I M and Soden B J 2000 *Ann. Rev. Energy Environ.* **25** 441–75
CrossRef Link | Order from Infotrieve
Helten M, Smit H G J, Strater W, Kley D, Nedelec P, Zoger M and Busen R 1998 *J. Geophys. Res.* **103** 25643–52
CrossRef Link | Order from Infotrieve
Heymsfield A J and Sabin R M 1989 *J. Atmos. Sci.* **46** 2252–64
CrossRef Link | Order from Infotrieve
Jensen E and Toon B 1997 *Geophys. Res. Lett.* **24** 249–52
CrossRef Link | Order from Infotrieve
Kärcher B 1996 *Geophys. Res. Lett.* **23** 1933–6
CrossRef Link | Order from Infotrieve
Karcher B and Lohmann U 2003 *J. Geophys. Res.* **108** 4402
CrossRef Link | Order from Infotrieve
Kärcher B, Mohler O, DeMott P J, Pechtl S and Yu F 2007 *Atmos. Chem. Phys.* **7** 4203–27
Order from Infotrieve
Karcher B and Spichtinger P 2009 *Clouds in the Perturbed Climate System* ed J Heintzenberg and R J Charlson (Cambridge, MA: MIT Press) p 597
Karcher B and Ström J 2003 *Atmos. Chem. Phys.* **3** 823–38
Order from Infotrieve
Koop T 2004 *Z. Phys. Chem.* **218** 1231–58
CrossRef Link | Inspec Abstract | Order from Infotrieve
Koop T, Luo B, Tsias A and Peter T 2000 *Nature* **406** 611–4
CrossRef Link | PubMed Abstract | Order from Infotrieve
Lenton T M and Vaughan N E 2009 *Atmos. Chem. Phys. Discuss.* **9** 2559–608
Order from Infotrieve
Lin R-F, Starr D O C, DeMott P J, Cotton R, Sassen K, Jensen E, Karcher B and Liu X 2002 *J. Atmos. Sci.* **59** 2305–29
CrossRef Link | Order from Infotrieve
Lohmann U 2009 personal communication
Lohmann U, Spichtinger P, Jess S, Peter T and Smit H 2008 *Environ. Res. Lett.* **3** 045022

XIX, 10

IOP Article
Mitchell D L and Heymsfield A J 2005 *J. Atmos. Sci.* **62** 1637–44
CrossRef Link | Order from Infotrieve
Mitchell D L, d'Entremont R P and Lawson R P 2009 *J. Atmos. Sci.* submitted
Mitchell D L, Rasch P J, Ivanova D, McFarquhar G M and Nousiainen T 2008 *Geophys. Res. Lett.* **35** L09806
CrossRef Link | Order from Infotrieve
Möhler O, Linke C, Saathoff H, Schnaiter M, Wagner R, Mangold A, Kramer M and Schurath U 2005a *Meteorol. Z.* **14** 477–84
CrossRef Link | Order from Infotrieve
Mohler O *et al* 2003 *Atmos. Chem. Phys.* **3** 211–23
Order from Infotrieve
Mohler O *et al* 2005b *J. Geophys. Res.* **110** D11210
CrossRef Link | Order from Infotrieve
Read W G, Waters J W, Wu D L, Stone E M and Shippony Z 2001 *J. Geophys. Res.* **106** 32207–58
CrossRef Link | Order from Infotrieve
Richardson M S *et al* 2007 *J. Geophys. Res.* **112** D02209
CrossRef Link | Order from Infotrieve
Sanderson B M, Piani C, Ingram W J, Stone D A and Allen M R 2008 *Clim. Dyn.* **30** 175–90
CrossRef Link | Order from Infotrieve
Sassen K and Dodd G C 1988 *J. Atmos. Sci.* **45** 1357–69
CrossRef Link | Order from Infotrieve
Spichtinger P, Gierens K and Read W 2003 *Q. J. R. Meteorol. Soc.* **129** 3391–410
CrossRef Link | Order from Infotrieve
Spichtinger P, Gierens K, Smit H G J, Ovarlez J and Gayet J F 2004 *Atmos. Chem. Phys.* **4** 639–47
Order from Infotrieve
Strom J *et al* 2003 *Atmos. Chem. Phys.* **3** 1807–16
Order from Infotrieve
Super A B 1986 *J. Clim. Appl. Meteorol.* **25** 1926–33
CrossRef Link | Order from Infotrieve
Trenberth K and Dai A 2007 *Geophys. Res. Lett.* **34** L15702
CrossRef Link | Order from Infotrieve
Wallace J M and Hobbs P V 1977 *Atmospheric Science* (New York: Academic) p 467
Warburton J A, Young L G and Stone R H 1995 *J. Appl. Meteorol.* **34** 121–30
CrossRef Link | Order from Infotrieve
Yin J H 2005 *Geophys. Res. Lett.* **32** L18701
CrossRef Link | Order from Infotrieve
Zuberi B, Bertram A K, Cassa C A, Molina L T and Molina M J 2002 *Geophys. Res. Lett.* **29** 1504
CrossRef Link | Order from Infotrieve

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APPENDIX 20

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ACTIVITY	FY88		FY89		FY90		FY91		FY92		FY93		FY94	
O's new	630		847		731		774		452		297		205	
O's rescinded	237		413		496		372		543		490		574	
otal SO's in effect, end of period	5122		5556		5791		6193		6102		5909		5540	
ponsoring Agencies for new SO's														
ASPAB/DTSA	113	*17.9%*	153	*18.1%*	170	*23.3%*	181	*23.4%*	75	*16.6%*	62	*20.9%*	68	*33*
ARMY	179	*28.4%*	107	*12.6%*	145	*19.8%*	93	*12.0%*	50	*11.1%*	29	*9.8%*	20	*9*
NAVY	159	*25.2%*	275	*32.5%*	205	*28.0%*	220	*28.4%*	132	*29.2%*	76	*25.6%*	48	*23*
AF	166	*26.3%*	292	*34.5%*	194	*26.5%*	265	*34.2%*	174	*38.5%*	105	*35.4%*	58	*28*
DOE	13	*2.1%*	20	*2.4%*	16	*2.2%*	15	*1.9%*	21	*4.6%*	25	*8.4%*	11	*5*
NASA	0	*0.0%*	0	*0.0%*	1	*0.1%*	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0*
lew DOD SO's imposed by Type														
DOD Type 1 (export control)	299	*47.5%*	356	*42.0%*	296	*40.5%*	362	*46.8%*	201	*44.5%*	31	*10.4%*	6	*2*
DOD Type 2 (lassified/classifiable)	158	*25.1%*	261	*30.8%*	151	*20.7%*	116	*15.0%*	95	*21.0%*	89	*30.0%*	64	*31.*
DOD Type 2 (foreign PSA)	113	*17.9%*	153	*18.1%*	170	*23.3%*	181	*23.4%*	75	*16.6%*	60	*20.2%*	67	*32*
DOD Type 3	47	*7.5%*	57	*6.7%*	97	*13.3%*	100	*12.9%*	60	*13.3%*	92	*31.0%*	57	*27*
lew Non-DOD SO's imposed OE,NASA)	13	*2.1%*	20	*2.4%*	17	*2.3%*	15	*1.9%*	21	*4.6%*	25	*8.4%*	11	*5*

ACTIVITY	FY95		FY96		FY97		FY98		FY99		FY00		FY01	
New Secrecy Orders	124		105		102		151		72		83		83	
SO's rescinded	324		277		210		170		210		245		88	
Total SO's in effect, end of period	5340		5168		5060		5041		4903		4741		4736	
Sponsoring Agencies for new SO's														
ASPAB/DTSA	38	*30.6%*	16	*15.2%*	35	*34.0%*	38	*24.7%*	0	*0.0%*	23	*27.7%*	17	*20.5%*
ARMY	11	*8.9%*	14	*13.3%*	4	*3.9%*	17	*11.0%*	24	*33.3%*	16	*19.3%*	11	*13.3%*
NAVY	23	*18.5%*	39	*37.1%*	39	*37.9%*	28	*18.2%*	13	*18.1%*	23	*27.7%*	30	*36.1%*
AF	37	*29.8%*	28	*26.7%*	24	*23.3%*	67	*43.5%*	20	*27.8%*	12	*14.5%*	25	*30.1%*
DOE	15	*12.1%*	8	*7.6%*	1	*1.0%*	4	*2.6%*	15	*20.8%*	9	*10.8%*	0	*0.0%*
NASA	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*	0	*0.0%*
New DOD SO's imposed by Type														
DOD Type 1 (export control)	3	*2.4%*	14	*13.3%*	14	*13.7%*	11	*7.3%*	5	*6.9%*	16	*19.3%*	7	*8.4%*
DOD Type 2 (classified/classifiable)	31	*25.0%*	45	*42.9%*	42	*41.2%*	37	*24.5%*	14	*19.4%*	20	*24.1%*	22	*26.5%*
DOD Type 2 (foreign PSA)	33	*26.6%*	16	*15.2%*	24	*23.5%*	15	*9.9%*	19	*26.4%*	24	*28.9%*	21	*25.3%*
DOD Type 3	42	*33.9%*	22	*21.0%*	21	*20.6%*	84	*55.6%*	19	*26.4%*	14	*16.9%*	33	*39.8%*
New Non-DOD SO's imposed (DOE,NASA)	15	*12.1%*	8	*7.6%*	1	*1.0%*	4	*2.6%*	15	*20.8%*	9	*10.8%*	0	*0.0%*
John Doe Sos					23		99		18		24		44	

ACTIVITY	FY02		FY03		FY04		FY05	
New Secrecy Orders	139		136		124		106	
SO's rescinded	83		87		80		76	
Total SO's in effect, end of period	4792		4841		4885		4915	
Sponsoring Agencies for new SO's								
ASPAB	60	*43.5%*	38	*27.9%*	22	*17.7%*	23	*21.7%*
ARMY	15	*10.9%*	23	*16.9%*	16	*12.9%*	14	*13.2%*
NAVY	16	*11.6%*	6	*4.4%*	8	*6.5%*	8	*7.5%*
AF	44	*31.9%*	65	*47.8%*	69	*55.6%*	46	*43.4%*
DOE	3	*2.2%*	4	*2.9%*	3	*2.4%*	6	*5.7%*
NSA	0	*0.0%*	0	*0.0%*	5	*4.0%*	9	*8.5%*
NIH	0	*0.0%*	0	*0.0%*	1	*0.8%*	0	*0.0%*
New DOD SO's imposed by Type								
DOD Type 1 (export control)	13	*9.4%*	8	*5.9%*	18	*14.5%*	11	*10.4%*
DOD Type 2 (classified/classifiable)	41	*29.5%*	36	*26.5%*	27	*21.8%*	42	*39.6%*
DOD Type 2 (foreign PSA)	60	*43.2%*	38	*27.9%*	23	*18.5%*	24	*22.6%*
DOD Type 3	22	*15.8%*	50	*36.8%*	52	*41.9%*	23	*21.7%*
Non-DOD SO's imposed (DOE,NASA)	3	*2.2%*	4	*2.9%*	4	*3.2%*	6	*5.7%*
John Doe SOs	37		51		61		32	

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ACTIVITY	FY03		FY04		FY05		FY06		FY07		FY08		FY09	
New Secrecy Orders	136		124		106		108		128		68		103	
SO's rescinded	87		80		76		81		68		47		45	
Total SO's in effect, end of period	4841		4885		4915		4942		5002		5023		5081	
Sponsoring Agencies for new SO's														
Foreign Origin	38	27.9%	22	17.7%	23	21.7%	3	2.8%	10	7.8%	10	14.7%	23	22.1%
ARMY	23	16.9%	16	12.9%	14	13.2%	2	1.9%	22	17.2%	8	11.8%	9	8.7%
NAVY	6	4.4%	8	6.5%	8	7.5%	36	33.3%	28	21.9%	8	11.8%	39	37.5%
Air Force	65	47.8%	69	55.6%	46	43.4%	40	37.0%	45	35.2%	20	29.4%	21	20.2%
Department of Energy	4	2.9%	3	2.4%	6	5.7%	7	6.5%	0	0.0%	2	2.9%	0	0.0%
National Security Agency (NSA)	0	0.0%	5	4.0%	9	8.5%	20	18.5%	21	16.4%	20	29.4%	12	11.5%
chnology Security Administration (DTSA)									2	1.6%	0	0.0%	0	0.0%
National Institue of Health (NIH)	0	0.0%	1	0.8%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
New DOD SO's imposed by Type														
DOD Type 1 (export control)	8	5.9%	18	14.5%	11	10.4%	19	17.6%	15	11.7%	21	30.9%	41	39.8%
DOD Type 2 (classified/classifiable)	36	26.5%	27	21.8%	42	39.6%	52	48.1%	68	53.1%	25	36.8%	24	23.3%
DOD Type 2 (foreign PSA)	38	27.9%	23	18.5%	24	22.6%	3	2.8%	11	8.6%	10	14.7%	23	22.3%
DOD Type 3 (general secrecy orders)	50	36.8%	52	41.9%	23	21.7%	27	25.0%	34	26.6%	10	14.7%	15	14.6%
w Non-DOD SO's imposed (DOE,NASA)	4	2.9%	4	3.2%	6	5.7%	7	6.5%	0	0.0%	2	2.9%	0	0.0%
John Doe Sos (imposed on private inventors)	51		61		32		29		53		22		21	

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U.S. DEPARTMENT OF COMMERCE
PATENT OFFICE
WASHINGTON, D.C. 20231

Serial No. 756,124 Filed Aug. 29, 1968

Applicant Gillis P. Flanagan

Title METHOD AND SYSTEM FOR SIMPLIFYING SPEECH WAVEFORMS

SECRECY ORDER

(Title 35, United States Code (1952), sections 181-188)

NOTICE: To the applicant above named, his heirs, and any and all his assignees, attorneys and agents, hereinafter designated principals.

You are hereby notified that your application as above identified has been found to contain subject matter, the unauthorized disclosure of which might be detrimental to the national security, and you are ordered in nowise to publish or disclose the invention or any material information with respect thereto, including hitherto unpublished details of the subject matter of said application, in any way to any person not cognizant of the invention prior to the date of the order, including any employee of the principals, but to keep the same secret except by written consent first obtained of the Commissioner of Patents, under the penalties of 35 U.S.C. (1952) 182, 186.

Any other application already filed or hereafter filed which contains any significant part of the subject matter of the above identified application falls within the scope of this order. If such other application does not stand under a secrecy order, it and the common subject matter should be brought to the attention of the Security Group, Licensing and Review, Patent Office.

If, prior to the issuance of the secrecy order, any significant part of the subject matter has been revealed to any person, the principals shall promptly inform such person of the secrecy order and the penalties for improper disclosure. However, if such part of the subject matter was disclosed to any person in a foreign country or foreign national in the U.S., the principals shall not inform such person of the secrecy order, but instead shall promptly furnish to the Commissioner of Patents the following information to the extent not already furnished: date of disclosure; name and address of the disclosee; identification of such part; and any authorization by a U.S. Government agency to export such part. If the subject matter is included in any foreign patent application, or patent this should be identified. The principals shall comply with any related instructions of the Commissioner.

This order should not be construed in any way to mean that the Government has adopted or contemplates adoption of the alleged invention disclosed in this application; nor is it any indication of the value of such invention.

EDWIN L. REYNOLDS
First Assistant Commissioner

An example of the secrecy order that enables a government to confiscate a patent.

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APPENDIX 21

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Text of H.R. 2977 [107th]: Space Preservation Act of 2001

Oct 2, 2001 - Introduced in House. This is the original text of the bill as it was written by its sponsor and submitted to the House for consideration. This is the latest version of the bill currently available on GovTrack.

HR 2977 IH

107th CONGRESS

1st Session

H. R. 2977

To preserve the cooperative, peaceful uses of space for the benefit of all humankind by permanently prohibiting the basing of weapons in space by the United States, and to require the President to take action to adopt and implement a world treaty banning space-based weapons.

IN THE HOUSE OF REPRESENTATIVES

October 2, 2001

Mr. KUCINICH introduced the following bill; which was referred to the Committee on Science, and in addition to the Committees on Armed Services, and International Relations, for a period to be subsequently determined by the Speaker, in each case for consideration of such provisions as fall within the jurisdiction of the committee concerned

---

A BILL

To preserve the cooperative, peaceful uses of space for the benefit of all humankind by permanently prohibiting the basing of weapons in space by the United States, and to require the President to take action to adopt and implement a world treaty banning space-based weapons.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the `Space Preservation Act of 2001'.

SEC. 2. REAFFIRMATION OF POLICY ON THE PRESERVATION OF PEACE IN SPACE.

Congress reaffirms the policy expressed in section 102(a) of the National Aeronautics and

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Space Act of 1958 (42 U.S.C. 2451(a)), stating that it \`is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind.'.

SEC. 3. PERMANENT BAN ON BASING OF WEAPONS IN SPACE.

The President shall--

(1) implement a permanent ban on space-based weapons of the United States and remove from space any existing space-based weapons of the United States; and

(2) immediately order the permanent termination of research and development, testing, manufacturing, production, and deployment of all space-based weapons of the United States and their components.

SEC. 4. WORLD AGREEMENT BANNING SPACE-BASED WEAPONS.

The President shall direct the United States representatives to the United Nations and other international organizations to immediately work toward negotiating, adopting, and implementing a world agreement banning space-based weapons.

SEC. 5. REPORT.

The President shall submit to Congress not later than 90 days after the date of the enactment of this Act, and every 90 days thereafter, a report on--

(1) the implementation of the permanent ban on space-based weapons required by section 3; and

(2) progress toward negotiating, adopting, and implementing the agreement described in section 4.

SEC. 6. NON SPACE-BASED WEAPONS ACTIVITIES.

Nothing in this Act may be construed as prohibiting the use of funds for--

(1) space exploration;

(2) space research and development;

(3) testing, manufacturing, or production that is not related to space-based weapons or systems; or

(4) civil, commercial, or defense activities (including communications, navigation, surveillance, reconnaissance, early warning, or remote sensing) that are not related to space-based weapons or systems.

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SEC. 7. DEFINITIONS.

In this Act:

(1) The term `space' means all space extending upward from an altitude greater than 60 kilometers above the surface of the earth and any celestial body in such space.

(2)(A) The terms `weapon' and `weapons system' mean a device capable of any of the following:

(i) Damaging or destroying an object (whether in outer space, in the atmosphere, or on earth) by--

(I) firing one or more projectiles to collide with that object;

(II) detonating one or more explosive devices in close proximity to that object;

(III) directing a source of energy (including molecular or atomic energy, subatomic particle beams, electromagnetic radiation, plasma, or extremely low frequency (ELF) or ultra low frequency (ULF) energy radiation) against that object; or

(IV) any other unacknowledged or as yet undeveloped means.

(ii) Inflicting death or injury on, or damaging or destroying, a person (or the biological life, bodily health, mental health, or physical and economic well-being of a person)--

(I) through the use of any of the means described in clause (i) or subparagraph (B);

(II) through the use of land-based, sea-based, or space-based systems using radiation, electromagnetic, psychotronic, sonic, laser, or other energies directed at individual persons or targeted populations for the purpose of information war, mood management, or mind control of such persons or populations; or

(III) by expelling chemical or biological agents in the vicinity of a person.

(B) Such terms include exotic weapons systems such as--

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(i) electronic, psychotronic, or information weapons;

(ii) chemtrails;

(iii) high altitude ultra low frequency weapons systems;

(iv) plasma, electromagnetic, sonic, or ultrasonic weapons;

(v) laser weapons systems;

(vi) strategic, theater, tactical, or extraterrestrial weapons; and

(vii) chemical, biological, environmental, climate, or tectonic weapons.

(C) The term `exotic weapons systems' includes weapons designed to damage space or natural ecosystems (such as the ionosphere and upper atmosphere) or climate, weather, and tectonic systems with the purpose of inducing damage or destruction upon a target population or region on earth or in space.

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APPENDIX 22

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etc group
action group on erosion, technology and concentration

ETC Group
News Release
February 11, 2010
www.etcgroup.org

Top-down Planet Hackers Call for Bottom-up Governance

Geoengineers Bid to Establish Voluntary Testing Regime Must be Opposed

While most scientists left the Copenhagen Climate Summit feeling gloomy about their influence, a small group of geoengineering advocates came away emboldened by the summit's weak outcome and uncertain road ahead. This group of scientists aims to get on with research and experimentation in controversial geoengineering technologies. Their real excitement is over "solar radiation management" (SRM). This is a way of "cooling down the planet's thermostat" by reflecting a portion of the sun's rays back to outer space, through a variety of techniques ranging from sunshades in space, to aerosol sulphates in the stratosphere, to whitening clouds. These high-risk, planet-altering schemes affect global warming without changing its cause which is excessive greenhouse gases in the atmosphere.

The roll-out of geoengineering as Plan B is being skillfully executed: prominent high-level panels sponsored by prestigious groups, a spate of peer-reviewed articles this January in science journals, and a line-up of panicked politicians in northern countries, nodding nervously in agreement as scientists testify about the "need to research Plan B."[1] "This lobbying offensive has been underway for more than a year now but it has moved into a critical new phase. The world needs to pay attention," said Diana Bronson of ETC Group, a technology watchdog headquartered in Canada. "Geoengineers are now advocating real-world experiments with some of the most high-risk climate changing technologies and many of them have no intention of waiting for an international regulatory agreement. Governments need to tell them they have no right to geoengineer the planet. Industrialized countries, which caused the problem of global warming in the first place, cannot be trusted to unilaterally attempt a techno-fix that will be even remotely equitable in its impact."

David Keith, a Canadian physicist who advises Bill Gates on his geoengineering grants, has shown the most bravado for experimenting with "fast, cheap and imperfect" technologies as "a hedge." In the science journal *Nature*[2] for example, he and his co-authors call for an international programme of SRM research to grow one-hundred-fold (from $10 million to $1 billion over ten years). This would include experiments at a scale that is large enough for the climate to notice but small enough to "limit risks." The article, which attracted extensive popular media attention, also addresses the thorny governance question, framing it as an issue of "establishing legitimate collective control" over reckless unilateral action. Yet Keith and his co-authors argue *against* the negotiation of an international treaty – or any kind of international regulation – which could prove "burdensome" on research or even result in a testing ban. Rather they call for a "bottom-up approach," where stakeholders could be "loosely" engaged and where

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an "iterative" relation could be established between the scientists and a select group of former politicians and NGO leaders who would study governance options, *while testing actually gets underway*. Keith's message to politicians is simple: keep the scientists in control of the discussion while inviting others to join; ensure it remains supportive of an ambitious research and testing agenda; and do NOT get the United Nations involved.[3]

Another article published in the last fortnight in *Science*[4] tackles the "Politics of Geoengineering." The authors, Blackstock and Long, also argue in favour of more SRM research and "subscale" experimentation, but caution against actual "climatic impacts research" (i.e. deployment) until an international framework is in place that can "facilitate this process." Rather, they politely ask scientists to "forswear climatic impacts testing and carefully restrict subscale field-testing until approved by a broad, legitimate international process." They endorse a voluntary process whereby scientists establish their own norms, as they plan to do at a meeting in Asilomar, California in late March as a "first step."[5] The notion of a "voluntary code" to govern geoengineering research and testing has been promoted by private ocean fertilization firms as well as by the UK Royal Society.[6] Civil society groups are concerned that this discussion is pre-empting a more fundamental international debate about whether or not geoengineering should be pursued at all.

In the same issue of *Science*, Alan Robock et al.[7], provide evidence of how dangerous actual testing of stratospheric aerosols would be, showing that solar radiation management "cannot be tested without full-scale implementation" and that this "could disrupt food production on a large scale." A large continuous dose of aerosols would be required to be able to distinguish actual climate impacts from regular weather "noise." Such deployment – the equivalent of one 1991 Mount Pinatubo eruption every 4 years—could indeed lower global average surface air temperature. But it would also affect the water and food supplies of more than 2 billion people!

Anyone who thinks these ideas are still marginal should tune into the joint hearings on geoengineering by the Committees on Science and Technology of the US House of Representatives and the UK House of Commons. Over the past three months, a parade of advocates has been drowning out more cautionary voices. In addition:

- Bill Gates has poured millions of dollars into geoengineering-related research since 2007[8] and Microsoft's former chief technical officer Nathan Myhrvold has become a champion of SRM. Myhrvold's firm Intellectual Ventures already has several patents pending on geoengineering technologies.[9]
- Billionaire Richard Branson has created a "Climate War Room"[10] to work with "the right stakeholders" to "create a strategic roadmap for governance and regulation" in the geoengineering "battle area."
- Several new research funding programmes and think tanks are being set up, mainly in the USA and UK.
- Vladmir Putin's key science advisor, Yuri Izrael directed a small-scale sulphate aerosol experiment in Russia last year that did not even hit the public radar until it was picked up on a popular blog.[11]

"It is one thing to examine geoengineering through computer modeling and laboratory testing. It is quite another for the richest men and the richest countries in the world to

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begin actual experiments that tinker with the planet's complex climate system that we do not fully understand. Suggesting a 'bottom-up,' governance process for such top-down planet-altering technologies is absurd. If they want a real 'bottom-up' process, they need to start with the people at the bottom who have already been affected by industry-induced climate change. Gates, Branson and the elite geoengineers are a long-way from the bottom. I'm sure they will keep their bottoms dry – and make money at the same time – no matter what happens to the planet. The geoengineering lobby has no mandate and no right to 'manage solar radiation' on behalf of anyone," says Silvia Ribeiro of ETC Group's Mexico office.

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ENDNOTES

[1] See for example the series of panels on geoengineering organized by the Royal Society and its partners at the Bella Centre in Copenhagen, archived at http://www.cigionline.org/articles/2009/12/cop-15-side-event-international-governance-geoengineering-research; Fareed Zakaria's long interview with Nathan Myhrvold on CNN, the day after Copenhagen failed at http://www.cnn.com/video/#/video/podcasts/fareedzakaria/site/2009/12/20/gps.podcast.12.20.cnn?iref=allsearch; David Keith's article in *Nature*, "Research on Global Sunblock Needed now" (see below) registers 112 news hits in a Google news search; Joint hearings on geoengineering governance are underway in the USA and the UK and most of the people invited to testify so far are actively involved in research and development of the field. See Press release, "Sub-Committee Examines Geoengineering Strategies and Hazards" at http://science.house.gov/press/PRArticle.aspx?NewsID=2741 and Press release, "New Enquiry: The Regulation of Geoengineering" at http://www.parliament.uk/parliamentary_committees/science_technology/s_t_pn10_091105.cfm.

[2] David Keith, Ed Parsons and Granger Morgan, "Research on Global Sun Block Needed Now," *Nature*, Vol. 463, 28 Jan 2010 available (to subscribers) at http://www.nature.com/nature/journal/v463/n7280/full/463426a.html

[3] See also David Keith's testimony before the UK Parliamentary Committee on Science and Technology at http://www.publications.parliament.uk/pa/cm200910/cmselect/cmsctech/uc221-i/uc22102.htm.

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[4] Jason J. Blackstock and Jane C. S. Long, "The Politics of Geoengineering," *Science*, 29 January 2010, Vol. 327. no. 5965, p.527.
[5] See the conference announcement on the Geoengineering Google Group: http://groups.google.com/group/geoengineering/browse_thread/thread/a573142a46029eb8/56b306ddbd7c3498?lnk=gst&q=Asilomar#56b306ddbd7c3498 .
[6] See UK Royal Society, *Geoengineering the Climate: Science, Governance and Uncertainty*, 2009, Recommendation 7, page 61. The California start-up Climos also promotes a voluntary code for ocean fertilization at http://www.climos.com/standards/codeofconduct.pdf.
[7] Alan Robock, Martin Bunzl, Ben Kravitz, Georgiy L. Stenchikov, "A Test for Geoengineering?" *Science*, 29 January 2010, Vol. 327. no. 5965, pp. 530-31.
[8] Eli Kintisch, "Bill Gates Funding Geoengineering Research," Science Insider, 26 January 2010 available at http://blogs.sciencemag.org/scienceinsider/2010/01/bill-gates-fund.html
[9] See ETC Group, *Retooling the Planet? Climate Chaos in a Geoengineering Age*, Swedish Society for Nature Conservation, 2009, p. 30.
[10] See www.carbonwarroom.com .
[11] See Chris Mooney, "Copenhagen: Geoengineering's Big Break?" http://motherjones.com/environment/2009/12/copenhagen-geoengineerings-big-break. See also Yu A. Izrael et al., "Field Experiment on Studying Solar Radiation Passing Through Aerosol Layers", Russian Meteorology and Hydrology, 2009, vol 34, no. 5, pp. 265-273.

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APPENDIX 23

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eurofins

environnement

N° échantillon : **08E011098-003**
Version du : 04/11/2008 16:37

RAPPORT D'ANALYSE

Date de réception :	28/10/2008
Référence dossier :	Demande d'analysesdu 20/10/08 selon devis N°FVBA200803490 - Métaux sur sols et eaux souterraines
Référence échantillon :	PAC
Matrice :	Sol
Début d'analyse :	28/10/2008

Résultats

Paramètres	Méthodes	Résultats	Unités	LQI
Préparation pour analyses physico-chimiques	NF ISO 11464			
* Préparation physico-chimique (séchage à 40°C)		-	-	
* Refus pondéral à 2 mm		35.0	% P.B.	1
* Minéralisation Eau Régale - Bloc chauffant après préparation	NF EN 13346	-	-	
Métaux par ICP/AES après minéralisation	NF EN ISO 11885			
Aluminium		7830	mg/kg M.S.	5
* Baryum		70.2	mg/kg M.S.	1

LQI : Limite de Quantification Inférieure. Les LQI sont fournies à titre indicatif, elles sont sous la responsabilité du laboratoire et fonction de la matrice.

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N° echantillon : **08E011098-002**
Version du : 04/11/2008 16:37

RAPPORT D'ANALYSE

Date de reception :	28/10/2008
Reférence dossier :	Demande d'analysesdu 20/10/08 selon devis N°FVBA200803490 - Métaux sur sols et eaux souterraines
Reférence échantillon :	PGB
Matrice :	Sol
Début d'analyse :	28/10/2008

Resultats

Parametres	Methodes	Résultats	Unites	LQI
Préparation pour analyses physico-chimiques	NF ISO 11464			
* Preparation physico-chimique (sechage a 40°C)		-	-	
* Refus pondéral a 2 mm		36.5	% P.B.	1
* Mineralisation Eau Regale - Bloc chauffant apres preparation	NF EN 13346	-	-	
Metaux par ICP/AES apres mineralisation	NF EN ISO 11885			
Aluminium		837	mg/kg M.S.	5
* Baryum		14.4	mg/kg M.S.	1

LQI : Limite de Quantification Inferieure. Les LQI sont fournies a titre indicatif, elles sont sous la responsabilite du laboratoire et fonction de la matrice.

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eurofins

environnement

N° échantillon : **08E011098-001**

Version du : 04/11/2008 16:37

RAPPORT D'ANALYSE

Date de réception :	28/10/2008
Référence dossier :	Demande d'analysesdu 20/10/08 selon devis N°FVBA200803490 - Métaux sur sols et eaux souterraines
Référence échantillon :	PTE
Matrice :	Sol
Début d'analyse :	28/10/2008

Résultats

Paramètres	Méthodes	Résultats	Unités	LQI
Préparation pour analyses physico-chimiques	NF ISO 11464			
* Préparation physico-chimique (séchage à 40°C)		-	-	
* Refus pondéral à 2 mm		34.5	% P.B.	1
* Minéralisation Eau Régale - Bloc chauffant après préparation	NF EN 13346	-	-	
Métaux par ICP/AES après minéralisation	NF EN ISO 11885			
Aluminium		878	mg/kg M.S.	5
* Baryum		31.2	mg/kg M.S.	1

LQI : Limite de Quantification Inférieure. Les LQI sont fournies à titre indicatif, elles sont sous la responsabilité du laboratoire et fonction de la matrice.

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APPENDIX 24

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Aerotoxic syndrome: a descriptive epidemiological survey of aircrew exposed to in-cabin airborne contaminants

C WINDER

P FONTEYN

J-C BALOUET

The term "aerotoxic syndrome" was proposed in 1999 to describe the association of symptoms observed among flight crew and cabin crew who have been exposed to hydraulic fluid or engine oil vapours or mists. A descriptive epidemiological study was conducted to investigate the health effects of aircrew through a questionnaire mail-out. Most of the respondents (88%) reported that symptoms occurred after exposure to engine oil or hydraulic fluid leaks which caused odours and/or visible contamination in the cabin. Invariably, aircrew directly attributed their symptoms to exposure to in-cabin airborne contaminants. A comparison between 18 respondents from the United States and the 50 Australian respondents shows significant similarities in reported symptoms. There was sufficient commonality in reported symptoms to conclude a symptom basis for aerotoxic syndrome.

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KEYWORDS

- AVIATION INDUSTRY
- AEROTOXIC SYNDROME
- NEUROTOXICITY
- NEUROPSYCHOLOGICAL DYSFUNCTION
- AIRBORNE CONTAMINANTS

Introduction

The oils and hydraulic fluids used in aircraft engines can be toxic, and specific ingredients of oils can be irritating, sensitising and neurotoxic (including phenyl-alpha-naphthylamine, and tri-aryl phosphates such as tri-ortho-cresyl phosphate).[1,2] If oil or hydraulic fluid leaks occur, this contamination may be in the form of unchanged material, degraded material from long use, or combusted or pyrolised materials. These materials can contaminate aircraft cabin air in the form of gases, vapours, mists and aerosols. There are a number of possible situations that can arise whereby cabin air can become contaminated.[3] Significant contaminants include: aldehydes; aromatic hydrocarbons; aliphatic hydrocarbons; chlorinated, fluorinated, methylated, phosphate and nitrogen compounds; esters; and oxides.[4-6] An additional problem is the lower partial pressure of oxygen in the cabins of aircraft flying at altitude.[7]

To date, most studies that have been carried out to measure atmospheric contamination in aircraft as a result of engine oil or hydraulic fluid leaks are sufficiently flawed on procedural and methodological grounds so as to render their conclusions invalid. Further, no monitoring has occurred during a leak.

International aviation legislation such as the United States Federal Aviation Regulations and the airworthiness standards for aircraft air quality state that "crew and passenger compartment air must be free from harmful and hazardous concentrations of gases or vapors".[8] Where contamination of the air in flight decks and passenger cabins occurs that is sufficient to cause symptoms of discomfort, fatigue, irritation or toxicity, this contravenes such standards and legislation.

Inhalation is an important route of exposure, with exposure to uncovered skin being a less significant route (for example, following exposure to oil mists or vapours). Ingestion is unlikely.

Occasionally, such exposures may be of a magnitude to induce symptoms of toxicity. In terms of toxicity, a growing number of aircrew are developing symptoms following both short-term and long-term repeated exposures, including dizziness, fatigue, nausea, disorientation, confusion, blurred vision, lethargy and tremors.[9 11] Neurotoxicity is a major flight safety concern, especially where exposures are intense.[12]

The earliest case found in the literature was reported in 1977.[13] A previously healthy member of an aircraft flight crew was acutely incapacitated during flight with neurological impairment and gastrointestinal distress. His clinical status returned to normal within a day. The aetiology of his symptoms was related to an inhalation exposure to aerosolised or vapourised synthetic lubricating oil arising from a jet engine of his aircraft.

Other studies of chemical exposures in aircraft can be found in the literature, including a 1983 study of 89 cases of smoke/fumes in the cockpits of US Air Force aircraft, a 1983 study of Boeing 747 flight attendants in the US (this article linked the symptoms to ozone), a 1990 study of aerospace workers, and a 1998 study of BAe 146 flight crews in Canada over a four-month period.[9,14-16] A recent report of seven case studies considered to be representative of the common symptoms of irritancy and toxicity described similar symptoms.[10] They investigated different exposures and situations, and the range of symptoms in these studies was quite broad, affecting many body systems. However, there are common themes in symptom clusters in these studies, as shown in Table 1.

While Table 1 shows a long list of symptoms, it is possible to characterise many symptoms more consistently. For example, different studies may describe the same symptom as dizziness, loss of balance, light-headedness, feeling faint, feeling intoxicated, or disorientation. It would be incorrect to regard such symptoms as being entirely different from each other — they point to a basic neuropsychological dysfunction affecting balance. But, rather than dismissing such symptoms as being multitudinous and variable, it may be more appropriate to re-categorise symptoms with clearer definitions, so that the artificial distinctions between symptom reporting can be clarified, and a shorter list developed.[17]

TABLE 1

Studies reporting signs and symptoms in aircrew

	Number of cases/reports				
Symptoms	*89*[14]	*248*[15]	*53*[16]	*112*[9]	*7*[10]
Irritation of eyes, nose and throat					7/7
Eye irritation, eye pain	35%	74%	57%	24%	4/7
Blurred vision, loss of visual acuity	11%	13%		1%	4/7
Rashes, blisters (uncovered body parts)			36%		4/7
Sinus congestion	35%	54%		5%	2/7
Nose bleed		17%			1/7
Throat irritation, burning throat, gagging and coughing	2%	64%	57%	43%	2/7
Cough		69%			2/7
Difficulty in breathing, chest tightness		68%			3/7
Loss of voice		35%			1/7
Chest pains	7%	81%		6%	2/7
Respiratory distress, shortness of breath, breathing problems requiring oxygen		73%		2%	4/7
Fainting, loss of consciousness, "grey out"	4%	4%			3/7
Shaking, tremors, tingling	9%			3%	3/7
Numbness (fingers, lips, limbs), loss of sensation			8%	2%	4/7
Dizziness, loss of balance	47%			6%	4/7
Light-headedness, feeling faint or intoxicated	35%	54%		32%	7/7
Disorientation	26%			15%	4/7
Severe headache, head pressure	25%	52%		26%	7/7
Trouble thinking or counting, word blindness, confusion, coordination problems	26%	39%	42%		6/7
Memory loss, memory impairment, forgetfulness			42%		7/7
Behaviour modified, depression, irritability	26%	20%	60%		4/7
Nausea, vomiting, gastrointestinal symptoms	26%	23%	15%	8%	6/7
Abdominal spasms, cramps, diarrhoea	26%				3/7
Change in urine		3%	6%		
Joint pain, muscle weakness, muscle cramps		29%			2/7
Fatigue, exhaustion					7/7
Chemical sensitivity			32%		4/7

Against this background, a descriptive epidemiological study was conducted of aircrew, which investigated the development of symptoms during flight through the mail-out of a self-administered questionnaire. Because of industry sensitivities with regard to such a survey, it was designed to be independent of the aviation industry (that is, aircraft manufacturers, airline operators and unions were not involved in the design or conduct). Therefore, there was no formal process of requesting nominations and a description of survey objectives was not provided prior to nomination.

One of the aims of the present study was to identify whether aerotoxic syndrome was definable and, if so, the symptoms that might be considered indicative of such a condition.

Methodology

The survey

Selection process: The survey was voluntary. Survey participants were those aircrew who took the effort to identify themselves to the research project team as being interested in the survey, and who then agreed to complete and return the survey.

As noted above, there was no information or publicity prepared or circulated by the research team about the proposed survey. Officers in both flight attendants and pilots unions were aware of the study, and a statement was issued by the Flight Attendants' Association of Australia that it was not involved with the survey. Further, information flows rapidly within the Australian aviation industry and the principal investigator received many telephone and email inquiries. Some inquirers were suspicious about the independence of the survey, about the source of research funding and about the possibility that the survey had any undue influence from companies or unions. Many nominations were made only when guarantees of funding independence and assurances of nominator anonymity were provided by the research project team.

The aircrew volunteer database was compiled over a four-month period in late 2000. It was originally proposed to survey between 30 and 50 nominations, but it became apparent that this was an underestimate of those interested in participating. Eventually 117 aircrew volunteered to be part of the survey. Of these, 100 were nominations from Australian aircrew.

Survey mail-out: Survey questionnaires were sent out in January 2001. A response period of four months was specified. After this time, no further responses were included. Other responses have been received since the cut-off date, including 18 from two US airlines. Because the highest response rate was from Australian aircrew, data from Australian respondents are presented in this article, with a comparison between the Australian and US findings discussed later.

Response rate: Ultimately, 100 survey forms were sent out to Australian nominations and 50 replies were received (a response rate of 50%). As distinct from many other surveys, the research team did not send follow-up reminders to non-respondents. It is not known why 50 volunteers initially planned to be involved in the survey but then later declined. A response rate of 50% to a single mail-out is considered excellent, and could have been higher if there had been a follow-up to non-respondents.

Development of questionnaire

A three-page structured questionnaire was developed to survey aircrew volunteers. The questionnaire consisted of open-ended and closed questions, with extra space to add other comments.

The questionnaire was derived from pre-existing questionnaires that had been developed for collecting information at interviews to assess the experience of aircrew following adverse health outcomes from exposure to contaminants while flying.[10] Additions and modifications were made to the questionnaire to suit the present study. The questionnaire used in the present study was reviewed by the University of New South Wales Ethics Committee. It was considered that the questionnaire should not "lead" or prejudice the respondent, and extensive modifications were made to early drafts to ensure neutral language. The final questionnaire did not contain concepts such as air leaks, contamination or aerotoxic syndrome. The questionnaire was then trialled with 10 aircrew. Further, mainly editorial, modifications were made as a result of the trial.

Aircrew were initially asked to identify what, if any, health symptoms they had experienced while flying and the duration of these symptoms. These questions were open-ended and invited opportunities for in-depth qualitative responses. Respondents were asked to describe factors that may have contributed to any adverse health symptoms and outcomes.

The second part of the questionnaire consisted of a relatively long list of signs and symptoms within the following symptom categories: neuropsychological;

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neurological; senses; eye and skin; respiratory; cardiovascular; gastrointestinal; renal; endocrine; immunological; and reproductive. Respondents were asked to report whether they had experienced any of the listed symptoms.

Data analysis

Qualitative data were analysed by using the Statistical Package for the Social Sciences.[18] Given the possibility of selection and reporting bias, statistical analysis was not conducted on these data.

Qualitative open-ended responses were documented and descriptive quotations are included in this article.

Results

Demographic characteristics

Table 2 contains a demographic overview of respondents. Of the 50 crew surveyed, 28% were male and 72% were female. The majority of respondents were cabin crew (70%), with flight crew comprising the remaining 30%.

The age of respondents ranged from 26 years to 59 years, with a mean age of 40±8 years (the median was 38 years).

Years of experience in the industry ranged between two and 40 years. The mean number of years of experience in the aviation industry was 16±10 years.

Ansett employed 72% of respondents and National Jet Systems 22%. Most flew on BAe 146 aircraft (92%), with 56% flying the A320 aircraft. Several cabin crew flew both types of aircraft.

The vast majority of respondents (92%) reported that they were non-smokers and tended to abstain from alcohol (16%) or consume small quantities of alcohol occasionally (72%).

Contributing factors

Aircrew were asked to describe any factors that may have contributed to their symptoms. These questions were unprompted and individual open-ended comments were requested. Most of the respondents (88%) reported that their symptoms occurred after an assumed exposure to oil gases and fumes in the cabin. The common use of the word "fume" was often incorrect on technical grounds. Technically, a fume is an aerosol of solid particles generated by condensation from the gaseous, volatile or oxidised atomic state — not what were almost certainly vapours (the gaseous phase of a liquid at room temperature) or mists.

Invariably, respondents attributed these gases and "fumes" (vapours and mists) to possible oil leaks. As the nature of these exposure events cannot be adequately described in statistics and graphs, a few extracts from some of the respondents are reproduced below. These sometimes better describe the more alarming aspects of such exposures:

— Pilot, age 59: "I consider the symptoms suffered are a direct result of cockpit fumes on the BAe 146 aircraft. The greater the incidence of detectable fumes, the more apparent the symptoms ... also related to rate of flying. On leave, the symptoms reduced."

— Flight attendant, age 48: "I had an increased exposure of fumes on the BAe 146, when the cabin filled up with smoke, I could not see past row two on the aircraft. Since that incident both the Captain and First Officer have developed lung disease, I had breast cancer and another flight attendant has sued the airline because of health problems."

— Flight attendant, age 37: "Following the fume occurrence on the BAe 146 I had a metallic taste in my mouth, headache over the right eye, sore throat. Short-term symptoms included nausea, dizziness, lack of concentration, memory loss, stiff neck, stinging/itchy, weepy eyes, difficulty in concentrating while driving, 'heavy' head, unable to stand in the shower without falling over."

Over half of the respondents (54%) cited airconditioning problems as a reason for adverse health symptoms. Other factors included hypoxia (18%) and pressurisation problems (16%).

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TABLE 2

Overview of the aviation employees surveyed

Aviation employee characteristics	*Categories*	*Number of responses* n	%
Gender	Male	14	28
	Female	36	72
Age	20–29	4	8
	30–39	25	50
	40–49	13	26
	50–59	8	16
Years of experience in aviation industry	1–9	13	26
	10–19	19	38
	20–29	11	22
	30–39	5	10
	40+	2	4
Occupation	Flight crew	16	32
	Cabin crew	34	68
Airline	Ansett	36	72
	National Jet Systems/Airlink	12	24
	Northwest Airlines	2	4
Type of aircraft*	BAe 146	46	92
	A320	28	56
Alcohol	None	8	16
	Mild	36	72
	Moderate	5	10
	Heavy	1	2
Smoking	Current smoker	4	8
	Non-smoker	46	92

* This was a multiple response question, so the percentage was calculated by each item as a total of 50 responses.

Onset of symptoms

Adverse health symptoms as a result of exposure to oil fumes were reported by 47 (94%) of the respondents.

Almost all respondents (96%) reported adverse symptoms immediately while flying or on the same day as flying. A large number of respondents (82%) also experienced adverse symptoms that continued for at least one month from the time of exposure. Many respondents (74%) reported that they experienced symptoms for at least six months after exposure. The term "long-term effects" indicates an effect(s) persisting over a long period of time; however, the duration of what might be considered "a long period of time" has generated debate in this industry. Some view this as being at least over six months, others over decades. For the purposes of this article, an effect is considered long-term if it has been present for over a year. Long-term symptoms that remained or developed after at least one year of exposure were reported by 76% of respondents.

Amelioration of effects of exposure

Data on the manner in which effects of exposure were ameliorated are shown in Table 3. Under half of the respondents (42%) had mild symptoms that reduced on vacating the plane and subsided further after extended rest.

Those with more moderate symptoms (32%) used the oxygen on board the aircraft:

— Flight attendant, age 37: "At times, due to maintenance problems, aircraft are flown with one

TABLE 3
Amelioration of effects of exposure (including gender differences)

Gender	What happened: Fresh air/ sleep on landing	Oxygen used	Hospitalised	Doctor attended	N/A or no symptoms	Total %
Male*	10 (20%)	2 (4%)	0	0	2 (4%)	14 (28%)
Female*	11 (22%)	14 (27%)	8 (16%)	3 (6%)	0	36 (72%)
Total*	21 (42%)	16 (32%)	8 (16%)	3 (6%)	2 (4%)	50 (100%)

* Data expressed as number of respondents (%) (total n = 50).

airconditioning pack in service. I usually feel hypoxic on these flights and use oxygen. On other occasions, the problem is with oil leaks and then my symptoms re-occur. As I have removed myself from flying on the BAe 146 my symptoms have subsided."

— **Flight attendant, age 40:** "After the mechanical failure, hydraulic fuel leaked into the cabin. All of the cabin crew and four passengers became ill. Flight deck was on oxygen when the crew reported dizziness, nausea and confusion and extreme head pain."

One pilot was so affected by exposure that the aircraft was grounded until the symptoms subsided. Almost one quarter of respondents (22%) experienced severe symptoms and collapsed after exposure. Hospitalisation was necessary for 16% who were taken off the aircraft on a stretcher or wheelchair suffering from exposure to toxic fumes:

— **Flight attendant, age 40:** "All the cabin crew and some passengers were exposed to the fumes. My legs gave way ... I had to harness myself into my jump-seat. After landing, the crew were taken by company van to an emergency room. Hospitalised, the physician's diagnosis five hours after landing was probable inhalation injury — cognitive problems, speech slurred, headache, nausea. Twenty-four hours after exposure the Internist Doctor noted ataxia, coordination problems — diagnosis toxic encephalopathy. Day 3, the Neurologist documented toxic encephalopathy with significant cognitive dysfunction, memory loss, speech disorder — I cannot set a clock and cannot draw a cube. An MRI was given two days after incident, tissue damage was found in white matter, high signal intensity spots on the frontal lobe of the brain. Still experience long-term effects."

— **Flight attendant, age 24:** "On the day of the incident, within the first hour of smelling the fumes I had difficulty breathing and talking. I had spasms in my legs, was faint and felt very hot. On disembarking I fell to the floor, they put me on oxygen and wheeled me off in a wheelchair. I was on oxygen for the first hour in the first aid room and was unable to talk for the first hour. I was taken to the medical centre during which time I was in and out of consciousness."

On a gender basis, fresh air and sleep reduced symptoms for almost equal numbers of males (20%) and females (22%); however, females generally experienced more severe symptoms that required greater medical intervention. Females (28%) were over five times more likely to use oxygen than males (4%). Hospitalisation was required for 16% of females in comparison with no males requiring hospitalisation. Three women (6%) required attendance by a doctor, as opposed to no reported requirements for males seeking medical assistance (see Table 3).

Data on signs and symptoms

Data on symptoms are presented below on the basis of grouped symptoms or organ systems. Data are presented in graphical form, with the same axis dimension for respondents showing symptoms to make comparison easier. Where possible, data on the background incidence of such symptoms in the Australian population are provided to allow a comparison with background incidence, although comparison of the data below with the other forms of data may be problematic (for example, self-reported as opposed to physician-collected data). There are also problems with comparing total populations with workers in that the "healthy worker" effect may bias results, as would comparing males with females.[19,20]

Irritancy symptoms in eyes, skin and respiratory system

There are high levels of irritancy symptoms in the data presented in Figure 1, including eye irritation (76%) and skin problems (58%). These are consistent with exposure to an irritant, but this may not be the only cause (for example, they could also be caused by the low humidity in aircraft during flight). There are some gender differences, although these could be related to gender sample sizes.

Similarly, a number of the symptoms in Figure 2 show respiratory irritation, with 64% of respondents reporting breathing problems (75% in females) and 48% reporting chest tightness/wheezing.

There are problems in categorising self-reported symptoms such as breathing problems or respiratory irritation. There are some gender differences in the data, with apparently high rates of respiratory irritation in females.

Adverse respiratory health effects from exposures to, among others, oxides of nitrogen, ozone, sulphur dioxide and particulates either singularly or in combination, such as in exposure to aviation fuel or jet stream exhaust, have been known for some time.[1,9,11,14] Tunnicliffe et al found an association between high occupational exposures to aviation fuel or jet stream exhaust and excess upper and lower respiratory tract symptoms — in keeping with exposure to a respiratory irritant.[21] In their study, 51% of aviation workers had upper and lower respiratory symptoms, including cough with phlegm and runny nose.

Gastrointestinal/renal signs and symptoms

Nausea and vomiting are relatively common symptoms, and were reported by 58% of respondents.[22] In most cases these symptoms were associated with intensifying gastrointestinal symptoms (mainly in females) of abdominal spasms (20%), abdominal pain (10%) and diarrhoea (28%) (Figure 3).

Neuropsychological and neurological signs and symptoms

Symptom reporting rates were high for many neuropsychological symptoms, including intense headache (86%), dizziness and disorientation (72%), performance decrement (including changes in cognitive function) (70%), memory and recall problems (66%), and balance problems (62%) (Figure 4). Other symptoms, such as anxiety (50%) and depression (40%) are more global and harder to interpret. The consistency of neurological symptoms is quite striking, suggesting neuropsychological impairment of a general nature, as seen, for example, in exposure to volatile organic compounds, organophosphate compounds or carbon monoxide.[23-25] The significance of such phenomena remains problematic.[26]

While neuropsychological effects are often dismissed as being subjective or unquantifiable, intense headache at 86%, dizziness/disorientation at 72%, performance decrement at 70% or memory problems at 66% are not symptoms that should be dismissed in aircrew while performing their duties. The high rate of respondents reporting such effects is difficult to interpret, owing to the self-selection of respondents to, and reporting bias in, this survey. However, the incidence of neuropsychological symptoms in aircrew, especially in females, appears excessive.

While self-reporting of neuropsychological or neurological symptoms may contain elements of subjectivity, the incidence in both genders of neuropsychological or neurological symptoms such as tingling (40%), tremors (30%), seizures or loss of consciousness (14%) was based on the reporting of symptoms after a respondent had been examined by

FIGURE 1
Data on eye and skin irritation signs and symptoms

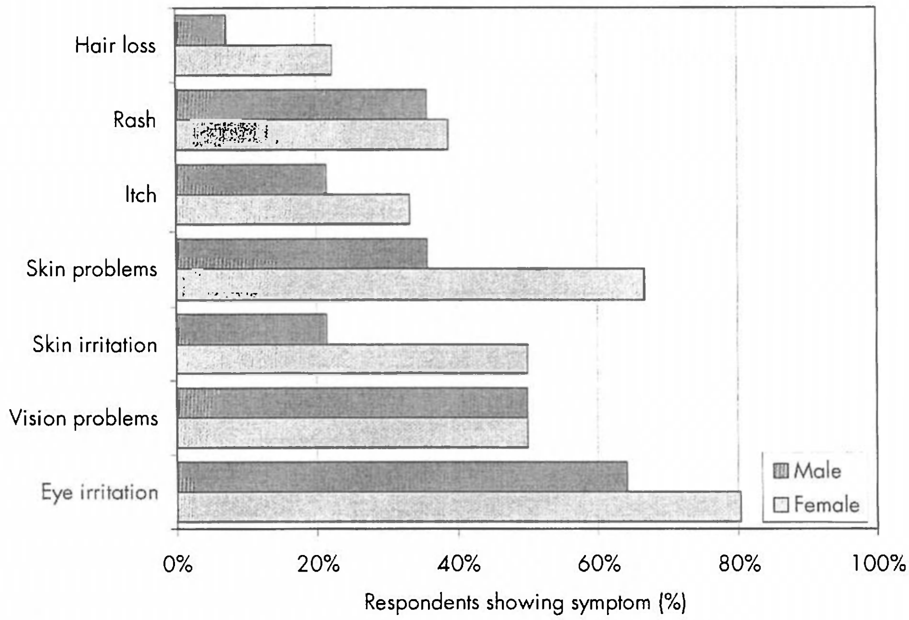

FIGURE 2
Data on respiratory and cardiovascular signs and symptoms

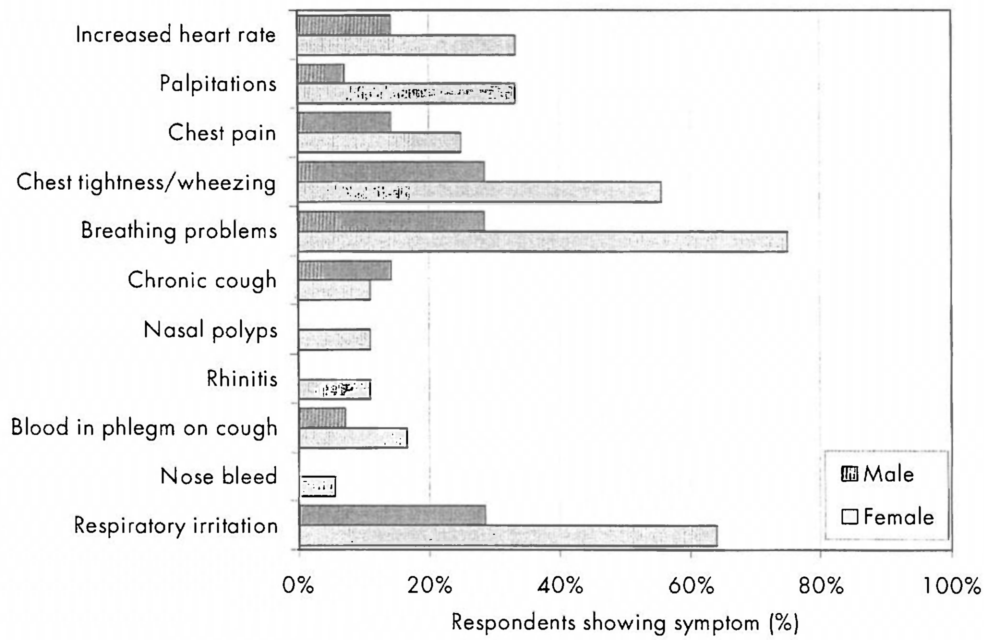

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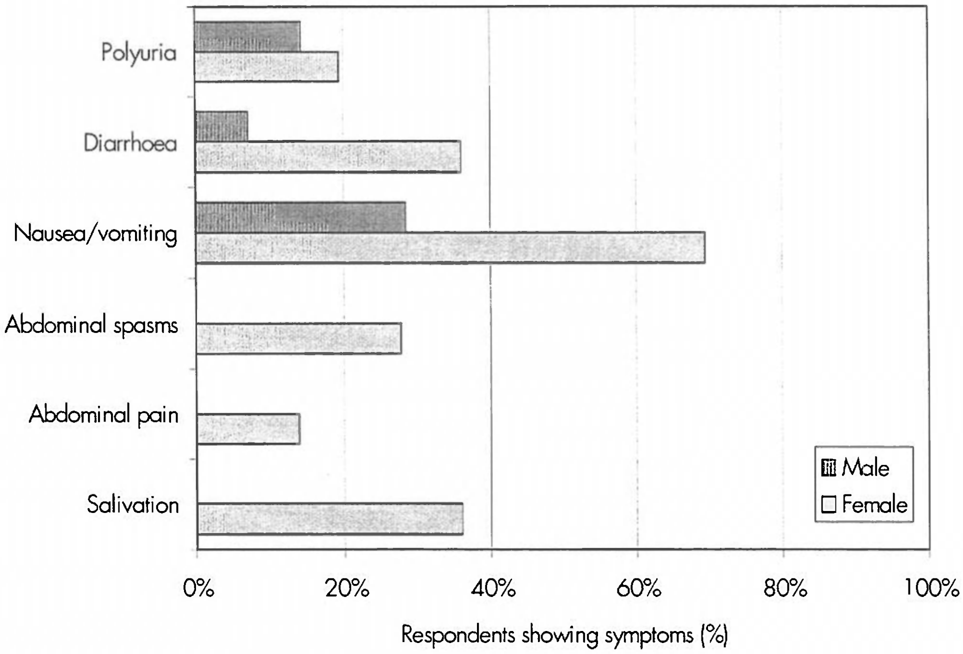
FIGURE 3
Data on gastrointestinal/renal signs and symptoms



their medical practitioner (Figure 5). These are significant symptoms that point to a toxic aspect of the exposures reported by respondents. Further, there may be a neurotoxic component to other symptoms, such as vision problems or disorientation or balance problems.

Reproductive signs and symptoms

There were 36 female respondents. All were of reproductive age, and many were planning to have or were having families during the time of their employment. Working women tend to have a lower fertility rate than non-working women, although this is for employment rather than biological reasons.[27] Fertility rates are falling in the developed nations for a range of reasons, and are estimated at 7–10%.[28] The data from respondents for reproductive symptoms are shown in Figure 6. Infertility was reported by 33% of respondents. This appears to be above population norms.

Menstrual dysfunction (variously reported as heavy periods, irregular periods or dysmennorrhoea) was reported by 28% of female respondents, miscarriage by 14% and multiple miscarriage by two respondents. Of particular significance is the problem of neonatal death in two respondents and genetic problems in the offspring of three respondents. While the sample size is small, these are noteworthy findings.

General signs and symptoms

As well as signs and symptoms in specific organ systems, a range of multi-organ or general symptoms was reported (Figure 7).

Joint pain (arthralgias) and muscle pain (myalgias) are common symptoms resulting from a variety of disease processes.[29,30] Despite the poorly understood pathogenetic mechanisms underlying myalgia and arthralgia, they are common in chronic fatigue and chemical sensitivity syndromes.

FIGURE 4
Data on neuropsychological signs and symptoms

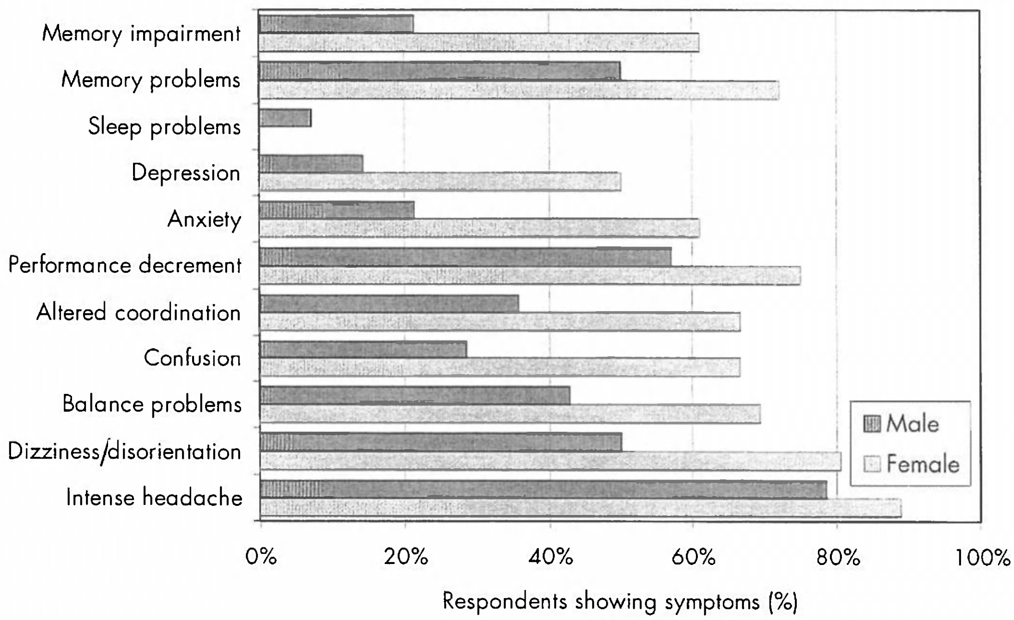


FIGURE 5
Data on neurological signs and symptoms

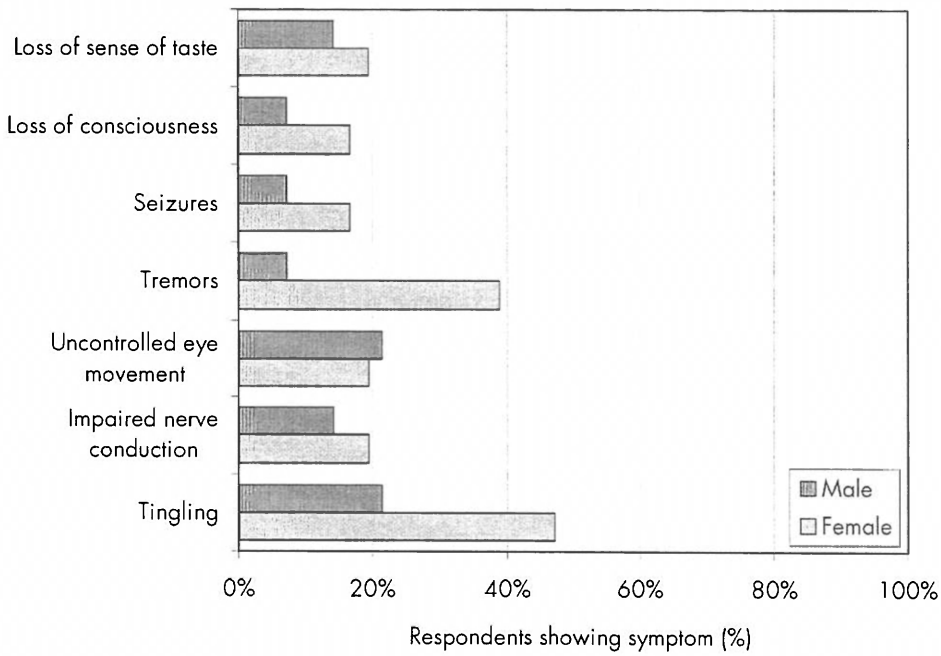


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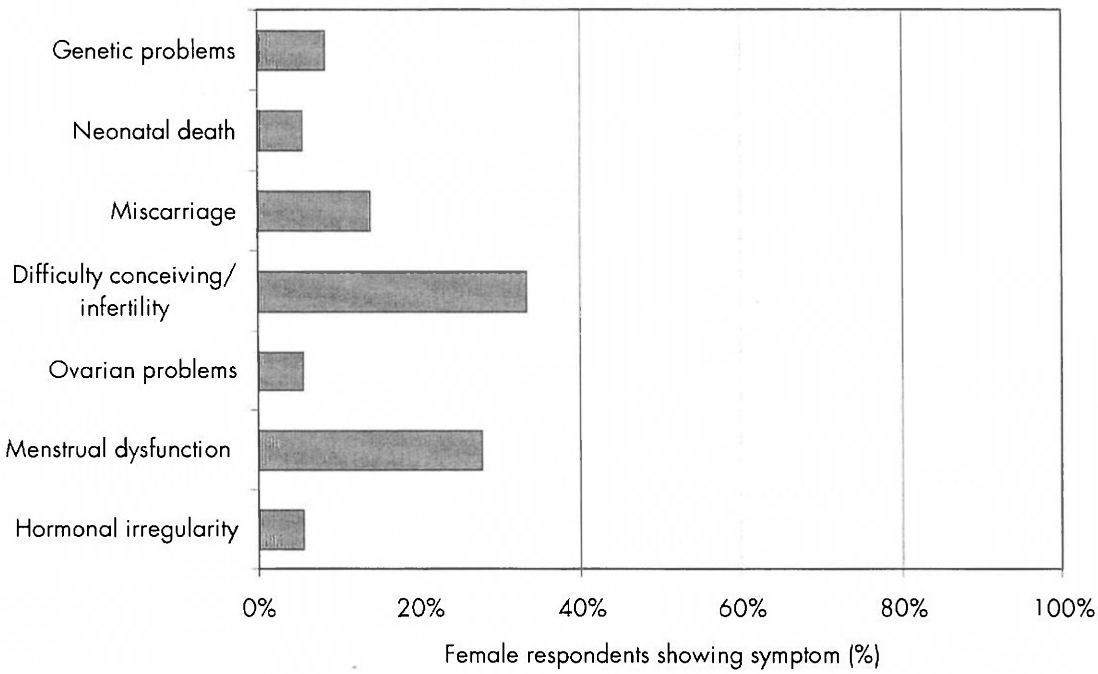
FIGURE 6
Data on reproductive signs and symptoms



Of the symptoms reported in this survey, exhaustion was the second most common, being reported by 78% of all respondents (89% of female respondents). Fatigue is an established hazard in aviation — from the perspective of the impairments in alertness and performance that it creates in pilots.[31] The exhaustion reported by respondents escalated into 72% of respondents reporting chronic fatigue. Prolonged or chronic fatigue is reported by about 25% of all patients presenting to Australian general practice.[32] Such fatigue states represent a continuum of severity ranging from the mild and transient symptoms through to the more rare, severe and prolonged fatigue disorders. In about 1% of patients attending general practice in Australia, the fatigue state will meet diagnostic criteria for chronic fatigue syndrome.[32] Figure 7 shows chronic fatigue at 36% for males and 72% for females. While there may be differences between diagnostic criteria for, and self-reporting of, chronic fatigue, these rates (particularly in females) are still very high.

A second cluster of symptoms was observed with chemical sensitivity. Allergies were reported by 34% of respondents, altered immune problems by 36% of respondents, and chemical sensitivity by 72% of respondents (83% of female respondents). Again, these are high rates that would almost certainly be well above any population background rate.

The co-occurrence and overlapping of many of the symptoms reported by the respondents is in keeping with comparable investigations. Co-morbidity of chronic fatigue, irritable bowel syndrome, chemical sensitivity, chronic headache and other unexplained conditions has only recently been systematically studied.[33] Comparative investigations in referral clinic populations have reported that in 53–67% of persons with chronic fatigue syndrome, illness worsens with exposure to various chemicals. Many patients with chronic fatigue syndrome also have irritable bowel syndrome (63%), multiple chemical sensitivity (41%) and other unexplained illness.[33]

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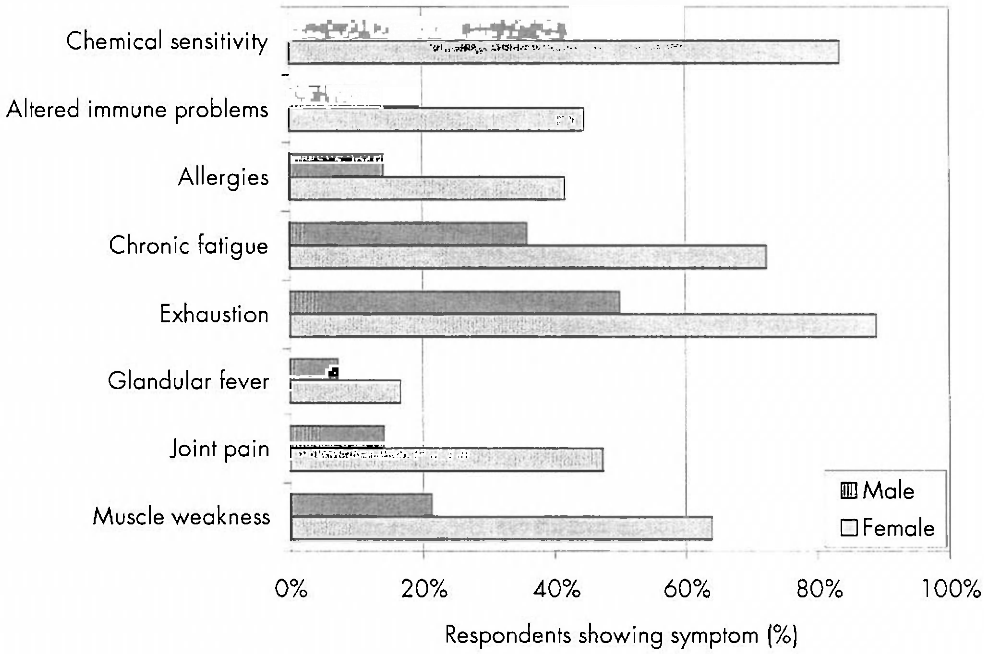
FIGURE 7
Data on general signs and symptoms



The US questionnaires

Eighteen questionnaires were submitted from respondents with addresses in North America (16 female; two male). Again, these were analysed descriptively. Rather than presenting the same data again (as in Figures 1 to 7), the symptom incidence for each symptom was plotted using an X,Y scatterplot, with the horizontal axis (X-axis) being the Australian symptom percentages and the vertical axis (Y-axis) being the US percentages (Figure 8).

These data show a number of symptoms where there is some difference between Australian and US symptom incidences, although in a few cases these outliers suggest diagnostic differences between the two countries (for example, chemical sensitivity/allergy). Nevertheless, there is a remarkable correlation between these data (correlation coefficient $r = 0.859$, $r^2 = 74\%$).

Discussion

The term "aerotoxic syndrome" was proposed in 1999 to describe the association of symptoms observed among aircrew who have been exposed to hydraulic fluid or engine oil smoke/fumes.[10,34]

With regard to the use of the term "syndrome", this is used to describe a set of symptoms that occur together, although generally there is no specification for the type and number of symptoms. Further, experience would suggest that the range and types of symptoms in such a symptom cluster would not be large.[17]

With regard to exposure to contaminants, while such exposures were not common, they were relatively frequent in certain models of aircraft. This study found two main types of exposure:

1. an "exposure event", where there was at least one self-reported intense exposure to contaminated air from an engine oil or hydraulic fluid leak; and

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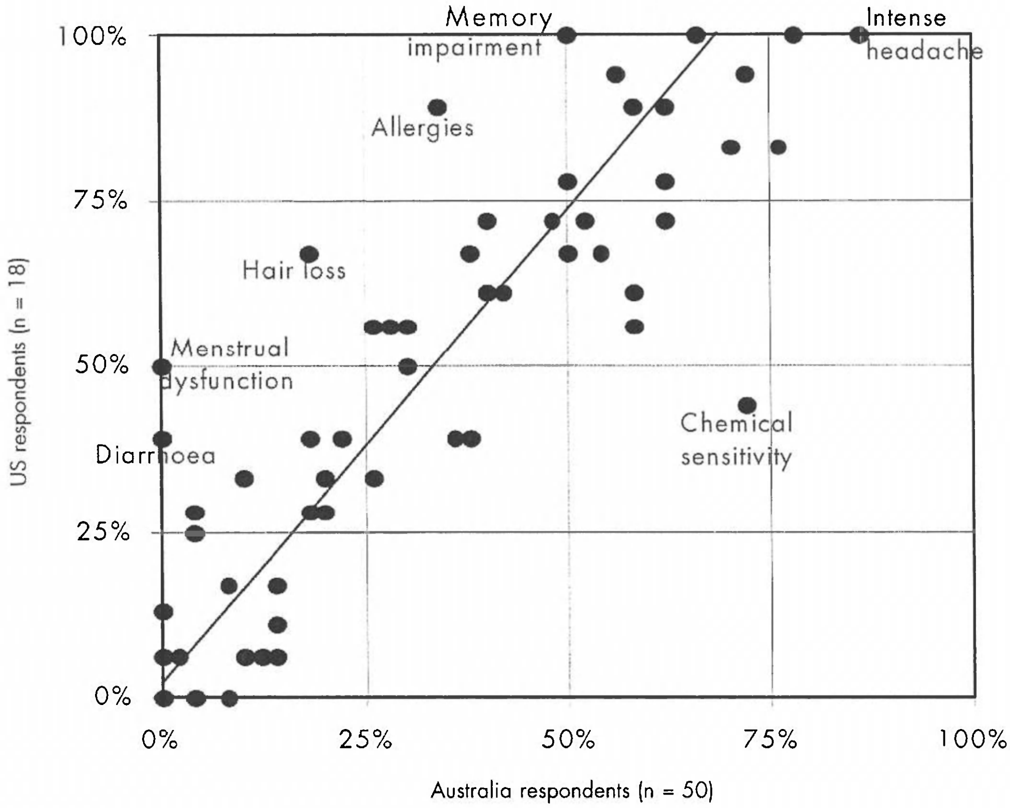
FIGURE 8
Comparison of Australian and US symptom incidences



2. self-reported residual exposure to odours and non-visible contamination.

While the majority of exposure events occurred during flight, it should be stressed that a number of leaks and exposures occurred on the ground. Engine seals are less efficient during engine warm up, during ground manoeuvring, and during transient operations (acceleration/deceleration). Further, prior to 1998, an operational procedure on some models of aircraft called an auxiliary pack unit burn out was carried out every day, whereby heated engine air was pumped through the passenger cabin to decontaminate heat exchangers, air ducts and filters. While operational procedures expressly excluded any person from being on the aircraft during pack burns, from 1992 to 1997 it was common for flight attendants to carry out early morning pre-flight checks on aircraft during pack burns — therefore, aircrew were exposed to contaminants. So, although major exposure events occurred during flight, ground operations should not be excluded as a source of exposure.

Although it was not possible to quantitatively assess exposure during exposure events, descriptions from visible haze to dense smoke suggest significant exposure.

Immediately after exposure, the symptoms are essentially those that can be observed in individuals who have been exposed to toxic irritants, such as eye irritation, respiratory irritation, headache and other short-term neuropsychological effects, skin problems and nausea. These symptoms usually recede after cessation of exposure. At least two Australian airlines have admitted that exposure events are significant enough to produce symptoms of irritation.[35,36]

However, it became apparent during this study that not all symptoms receded following cessation of exposure. Some existing symptoms became more debilitating, for example, headaches became so intense that they lasted for weeks and would not respond even to the most powerful over-the-counter analgesics. Neuropsychological symptoms became more generalised and affected more functions, with cognitive symptoms and recall problems becoming more significant. Skin itch became skin rash. Respiratory irritation became chest pain and/or difficulty in breathing. The intensification process was more likely to occur if exposure continued but, occasionally, would intensify even if exposure had ceased.

In addition, new symptoms began to emerge, including chronic fatigue, parathesias and numbness, myalgias, arthralgias, alcohol and food intolerances, and chemical sensitivity. Most of these symptoms continued even after exposure had ceased. Further, these and many of the neurological and neuropsychological symptoms worsened.[9 11]

The number of cases that emerged over the 1996 to 1999 period in Australia, North America and Europe became significant — to the extent that an appropriately designed epidemiological survey of aircrew was needed. The possibility of an industry-sponsored study seemed unlikely. Therefore, the present independent survey was conducted.

This survey comprised 117 individuals who nominated themselves to be entered into a database to receive a copy of the survey questionnaire. There were no criteria used to select study participants. The survey was carried out after a well-publicised Australian Senate Inquiry into air quality in the aviation industry, and this may have increased interest in some individuals to self-nominate.[37] The fact that so many respondents who had flown on those aircraft where engine leaks had occurred returned questionnaires was not intrinsically part of the survey. It is almost certain that self-nominations occurred through word of mouth as a result of contacts in the Australian aviation industry, and it is for this reason that there is a selection bias in the study respondents. No claim is made to suggest that the respondents in this survey are representative of any group in the aviation industry. The respondents represent themselves.

The survey questionnaire was designed to be neutral and contained no leading or biased questions. It was finalised after a trial with 10 aircrew. Eventually, 50 individuals from Australia returned completed surveys. Analysis of their surveys established similar findings to earlier studies (for example, see Table 1) with a moderate-sized group of respondents. Eighteen respondents returned questionnaires from North America — these were analysed separately.

In most cases it is not known whether the respondents' self-reporting was subjective or based on objective clinical or laboratory findings. This is a shortcoming of the survey. For example, the number of synonyms that exist for fatigue, that is, lack of energy, weakness, sleepiness, tiredness, lassitude, exhaustion, and so on, indicate the problems of assessing just one symptom.[38] In many cases, objective criteria exist for physicians to use in the diagnosis of such conditions. In some cases, respondents knew this and reported accordingly.

Patient diagnosis may also have been influenced by practice patterns in which their physicians specialised, that is, they reported symptoms diagnosed by specialists (not themselves). In other cases, agreement on case definitions of certain symptoms is not universal.[38] This overlap of symptoms and syndromes makes diagnosis complex.[33]

Conclusion

The range of epidemiology studies varies, and the predictive power of each type of study varies depending on design and methodological, analytical and interpretational factors. This survey was a descriptive survey of a group of non-representational individuals who qualitatively described workplace exposure scenarios and self-reported symptoms from such exposures. For this reason, no attempt has been

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made to ascribe causality or make inferences of a general nature. However, even with such procedural limitations, it was possible to draw a number of conclusions from this survey:

1. The hydraulics and lubricants used in the aviation industry contain a number of irritating and toxic ingredients.[6]

2. This study has shown that exposure to such contaminants, if they get into aircraft cabin air, can produce symptoms of toxicity.

3. The symptom clusters in aerotoxic syndrome can be described. These are:

— symptoms of dysfunction in neurological function immediately after intense exposures, including loss of positional awareness, vertigo and loss of consciousness. If these symptoms occur in a pilot, they are a significant aviation safety problem;

— symptoms of skin, eyes, nose and respiratory irritation immediately after exposure. Further exposures exacerbate the symptoms, often leading to other respiratory and cardiovascular effects;

— symptoms of gastrointestinal discomfort immediately after exposure. While these recede with cessation of exposure, there is a suggestion that nausea and diarrhoea can persist;

— some symptoms of impairment of neuropsychological function immediately after exposure, such as headache, dizziness, disorientation and intoxication. These symptoms become more debilitating after time, with problems of loss of cognitive function and memory problems emerging;

— general symptoms of exhaustion progressing to chronic fatigue. It was common for respondents to spend layovers, weekends and holidays sleeping for days to overcome the symptoms of exhaustion; and

— general symptoms of immune suppression developing some time after exposure, including food and alcohol intolerances, allergies and chemical sensitivity. These symptoms worsen with continuing exposure and may worsen even after exposure ceases.

Where symptoms of discomfort, irritation or toxicity occur, this breaches airworthiness legislation.

4. Many surveys of workers report that working populations generally enjoy a higher level of health than the populations from which they arise. This is the "healthy worker" effect, a commonly observed phenomenon by which lower death rates (or injury or disease rates) are observed in workers relative to the general population.[19,39] While this may be due to a selection bias problem, the aircrew in this survey had incidences of symptoms at much higher rates than population backgrounds — suggesting (in many cases) that they were unhealthier than the general population. However, as aircrew undergo regular health checks (pilots regularly, flight attendants less so), the levels of fitness and health in such individuals should be better than population norms.

5. There are a number of results from this study that require further investigation — particularly the findings of neurological impairment, respiratory system effects, reproductive dysfunction and other long-term effects.

Aerotoxic syndrome presents significant issues with regard to the health of pilots, cabin crew and passengers, but most notably with regard to air safety if pilots are incapacitated and cabin crew cannot supervise cabin evacuations during emergencies. Health effects include short-term irritant, skin, gastrointestinal, respiratory and nervous system effects, and long-term central nervous and immunological effects. Some of these effects are transient, others appear more permanent. The exacerbation of pre-existing health problems by toxic exposures is also highly probable.

There is also a hidden issue. Airline staff in Australia are worried about job security and what might happen to them if they complain about working conditions and make their symptoms public. This is especially apparent following the demise of a major Australian airline. At present, with only a few cases proceeding in

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the courts, little compensation has been awarded to airline workers affected by toxic gases, vapours and fumes. Therefore, many crew are flying while further compromising their health and safety, and will only come forward when they become concerned that they may not be able to continue flying, or worse, when they are no longer able to fly.

Acknowledgments

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References

1. Committee of Aviation Technology, Aero Medical Association. *Aviation toxicology: an introduction to the subject and a handbook of data*. Toronto: CAT, AMA, Blakiston, 1953.
2. Tupper, CR. Chemical hazards in aeromedical aircraft. *Aviat Space Environ Med* 1989, 60: 73-75.
3. American Society of Heating, Refrigerating and Air-conditioning Engineers. *Air quality within commercial aircraft: ASHRAE standard 161*. Atlanta: ASHRAE, 1999.
4. Mattie, DR, Hoeflich, TJ, Jones, CE, Horton, ML, Whitmire, RE, Godin, CS, Femming, CD and Andesen, ME. The comparative toxicity of operational air force hydraulic fluids. *Toxicol Ind Health* 1993, 9: 995-1016.
5. Hewstone, RK. Environmental health aspects of lubricant additives. *Sci Total Environ* 1994, 156: 243-254.
6. Winder, C and Balouet, J-C. Toxic ingredients in commercial jet fuels. *Environ Res* 2002, 89: 146-164.
7. Balouet, J-C, Kerguelen, M and Winder, C. Toxicity and hypoxia: hyperbaric pressure and LC_{50}s for carbon monoxide or hydrogen cyanide. *Toxicology* 2001, 164: 164.
8. United States Federal Aviation Authority. *Federal air regulations, transport category airplanes, airworthiness standards, section 25.831*. Washington: FAA, 1965.
9. Van Netten, C. Air quality and health effects associated with the operation of the BAe 146-200 aircraft. *Applied Occupational and Environmental Hygiene* 1998, 13: 733-739.
10. Balouet, J-C and Winder, C. *Aerotoxic syndrome in air crew as a result of exposure to airborne contaminants in aircraft*. Paper presented at the American Society of Testing and Materials Symposium on Air Quality and Comfort in Airliner Cabins, New Orleans, 27-28 October 1999.
11. Winder, C and Balouet, J-C. Aircrew exposure to chemicals in aircraft: symptoms of irritation and toxicity. *J Occup Health Safety — Aust NZ* 2001, 17(5): 471-483.
12. Bureau of Air Safety Inspection. *British Aerospace plc BAe 146-300 10 July 1997: preliminary report 9702276*. Canberra: BASI, 23 October 1997.
13. Montgomery, MR, Wier, GT, Zieve, FJ and Anders, MW. Human intoxication following inhalation exposure to synthetic jet lubricating oil. *J Toxicol Clin Toxicol* 1977, 11: 423-426.
14. Rayman, RB and McNaughton, GB. Smoke/fumes in the cockpit. *Aviat Space Environ Med* 1983, 54: 738-740.
15. Tashkin, DP, Coulson, AH, Simmons, MS and Spivey, GH. Respiratory symptoms of flight attendants during high altitude flight: possible relation to cabin ozone exposure. *Int Arch Occup Environ Health* 1983, 52: 117-137.
16. Sparks, PS, Simon, GE, Katon, WJ, Altman, LC, Ayars, GH and Johnson, RL. An outbreak of illness among aerospace workers. *West J Med* 1990, 158: 28-33.
17. United States National Academy of Science. *The airliner cabin environment and the health of passengers and crew*. Washington: NAS, National Academy Press, 2001.
18. SPSS Inc. *Statistical package for the social sciences (SPSS)* ® Version 9.05 for Windows. Chicago: SPSS Inc, 1999.
19. Monson, RR. Observations on the healthy worker effect. *Journal of Occupational Medicine* 1986, 28: 425-433.
20. Baillargeon, J, Wilkinson, G, Rudkin, L, Baillargeon, G and Ray, L. Characteristics of the healthy worker effect: a comparison of male and female occupational cohorts. *Journal of Occupational and Environmental Medicine* 1998, 40: 368-373.
21. Tunnicliffe, WS, O'Hickey, SP, Fletcher, TJ, Miles, JF, Burge, PS and Ayres, JG. Pulmonary function and respiratory symptoms in a population of airport workers. *Occup Environ Med* 1999, 56: 118-123.
22. Andrews, PL. Physiology of nausea and vomiting. *British Journal of Anaesthiology* 1992, 69 Suppl 1: 2S-19S.
23. Otto, DA. Assessment of neurobehavioral response in humans to low-level volatile organic compound sources. *Ann N Y Acad Sci* 1992, 641: 248-260.
24. Jamal, GA. Long term neurotoxic effects of organophosphate compounds. *Adverse Drug Reactions and Toxicological Reviews* 1995, 14: 85-99.

XXIV, 19

25. Raub, JA, Mathieu-Nolf, M, Hampson, NB and Thom, SR. Carbon monoxide poisoning: a public health perspective. *Toxicology* 2000, 145: 1-14.

26. Fiedler, N. Neuropsychological approaches for the detection and evaluation of toxic symptoms. *Environ Health Perspect* 1996, 104 Suppl 2: 239-245.

27. Lee, WR and McCloy, EC. Reproduction and work. *Br Med J* 1986, 293: 1521-1522.

28. European Society for Human Reproduction and Embryology Capri Workshop Group. Social determinants of human reproduction. *Hum Reprod* 2001, 16: 1518-1526.

29. Roy, EP and Gutmann, L. Myalgia. *Neurology Clinics* 1988, 6: 621-636.

30. Hart, FD. Arthralgia. *Annals of Physical Medicine* 1970, 10: 257-261.

31. Caldwell, JA. Fatigue in the aviation environment: an overview of the causes and effects as well as recommended countermeasures. *Aviat Space Environ Med* 1997, 68: 932-938.

32. Lloyd, AR, Hickie, IB and Loblay, RH. Illness or disease? The case of chronic fatigue syndrome. *Med J Aust* 2000, 172: 471-472.

33. Aaron, LA and Buchwald, D. A review of the evidence for overlap among unexplained clinical conditions. *Ann Intern Med* 2001, 134: 868-881.

34. Winder, C and Balouet, J-C. *Aerotoxic syndrome: adverse health effects following exposure to jet oil mist during commercial flights. Towards a safe and civil society.* In the proceedings of the International Congress on Occupational Health 2000, Brisbane, September 2000, pp 196-199.

35. Ansett Australia. *Consensus statement, external panel of specialists, BAe 146 odour occurrences.* Brisbane: Ansett Australia, 25 March 1998.

36. National Jet Systems. *NJS BAe 146 oil fumes in summary, November 1998.* Supplementary submission to the Senate Rural and Regional Affairs and Transport References Committee on the Inquiry into Air Safety — BAe 146 Cabin Air Quality. Canberra: Parliament of Australia, 2000.

37. Senate Rural and Regional Affairs and Transport References Committee. *Report on air safety and cabin air quality in the BAe 146 aircraft.* Canberra: Parliament of Australia, October 2000. Website at www.aph.gov.au//senate/committee/rrat_ctte/bae/bae.pdf.

38. Wessely, S. Chronic fatigue: symptom and syndrome. *Ann Intern Med* 2001, 134: 838-843.

39. McMichael, AJ. Standardised mortality ratios and the "healthy worker effect": scratching beneath the surface. *Journal of Occupational Medicine* 1976, 18: 165.

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APPENDIX 25

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2. HEALTH EFFECTS

2.1 INTRODUCTION

The primary purpose of this chapter is to provide public health.officials, physicians, toxicologists, and other interested individuals and groups with an overall perspective of the toxicology of jet fuels JP-4 and JP-7 and a depiction of significant exposure levels associated with various adverse health effects. It contains descriptions and evaluations of studies and presents levels of significant exposure for JP-4 and JP-7 based on toxicological studies and epidemiological investigations.

A glossary and list of acronyms, abbreviations, and symbols can be found at the end of this profile.

2.2 DISCUSSION OF HEALTH EFFECTS BY ROUTE OF EXPOSURE

To help public health professionals address the needs of persons living or working near hazardous waste sites, the information in this section is organized first by route of exposure- inhalation, oral, and dermal-and then by health effect-death, systemic, immunological, neurological, developmental, reproductive, genotoxic, and carcinogenic effects. These data are discussed in terms of three exposure periods-acute (14 days or less), intermediate (15-364 days), and chronic (365 days or more).

Levels of significant exposure for each route and duration are presented in tables and illustrated in figures. The points in the figures showing no-observed-adverse-effect levels (NOAELs) or lowest observed-adverse-effect levels (LOAELs) reflect the actual doses (levels of exposure) used in the studies. LOAELs have been classified into "less serious" or "serious" effects. These distinctions are intended to help the users of the document identify the levels of exposure at which adverse health effects start to appear. They should also help to determine whether or not the effects vary with dose and/or duration, and place into perspective the possible significance of these effects to human health.

The significance of the exposure levels shown in the tables and figures may differ depending on the user's perspective. For example, physicians concerned with the interpretation of clinical findings in exposed persons may be interested in levels of exposure associated with "serious" effects. Public health officials and project managers concerned with appropriate actions to take at hazardous waste

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sites may want information on levels of exposure associated with more subtle effects in humans or animals (LOAEL) or exposure levels below which no adverse effects (NOAEL) have been observed. Estimates of levels posing minimal risk to humans (Minimal Risk Levels, MRLs) may be of interest to health professionals and citizens alike.

The jet fuels JP-4 and JP-7 are liquid military aviation turbine fuels whose composition varies slightly with the nature of the crude petroleum from which they were derived (Dukek 1978). Jet fuels derived from crude oil, the common name for liquid petroleum, are referred to as petroleum-derived jet fuels. Jet fuels derived from an organic material found in shale that can be converted by heat to shale oil are called shale-derived jet fuels. JP-4 is a wide-cut fuel; this is a refinery term indicating that it is distilled from crude oil using a broad temperature range and consists of hydrocarbons in a wide range of chain-lengths (4 to 16 carbons long) (Air Force 1989b; CONCAWE 1985). It was developed by the U.S. Air Force in order to ensure fuel availability in times of war (Dukek 1978; ITC 1985). JP-7 is a kerosene with a high flash point and is used in advanced supersonic aircraft. The jet fuels are blends of various hydrocarbons, including alkanes (paraffins) and cycloalkanes (naphthenes), aromatics, and olefins, as well as small amounts of compounds such as benzene, n-hexane, and polycyclic aromatic hydrocarbons.

The purpose of this chapter is to consider the toxicological effects of exposure to the mixture JP-4 or JP-7. Exposure to jet fuel components, exhaust, or combustion products will not be discussed. For information concerning the possible toxicity associated with exposure to some of the individual components of jet fuels, the reader is referred to the ATSDR toxicological profiles for benzene (ATSDR 1991a), toluene (ATSDR 1990), total xylenes (ATSDR 1991c), and polycyclic aromatic hydrocarbons (ATSDR 1991b). In addition, because of the variable composition of the jet fuels, the molecular weights are unknown (Kinkead et al. 1974).

2.2.1 Inhalation Exposure

2.2.1 .I Death

No studies were located regarding death in humans after inhalation exposure to JP-4 or JP-7.

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2. HEALTH EFFECTS

Exposure of Sprague-Dawley rats to concentrations as high as 5,000 mg/m^3 shale- or petroleum derived JP-4 for 4 hours did not result in any mortality or apparent toxic signs during the 2-week post exposure holding period (Clark et al. 1989).

Intermediate-duration exposure of rats and mice to concentrations of JP-4 as high as 5,000 mg/m^3 resulted in death in 1 of 40 exposed mice and 1 of 50 exposed rats, between 4 and 6 months after the exposure was begun (Air Force 1974). It was concluded that exposure to the test substance was probably not responsible for the deaths of these animals since two unexposed mice and one unexposed rat also died and because there were no abnormal histological findings in the rat. No deaths occurred when dogs or monkeys were exposed to similar JP-4 concentrations for 8 or 6 months, respectively (Air Force 1974).

No increase in mortality was seen in chronic studies in which mice and rats were exposed intermittently (6 hours/day, 5 days/week) to as much as 5,000 mg/m^3 JP-4 (Air Force 1981i; Bruner et al. 1993) or in studies where rats were exposed to 750 mg/m^3 JP-7 (Air Force 19828, 1983e, 1991). Additionally, no increase in mortality was observed in rats or mice 12 months after chronic intermittent exposure (6 hours/day, 5 days/week) to 5,000 mg/m^3 JP-4 (Bruner et al. 1993).

2.2.1.2 Systemic Effects

No studies were located regarding cardiovascular, gastrointestinal, musculoskeletal, dermal or ocular effects in humans or animals after inhalation exposure to JP-7. No studies were located regarding gastrointestinal, musculoskeletal, dermal or ocular effects in humans after inhalation exposure to JP-4. No studies were located regarding musculoskeletal or dermal effects in animals after inhalation exposure to JP-4.

The highest NOAEL values and all reliable LOAEL values for systemic effects for each study and end point are recorded in Table 2-1 and plotted in Figure 2-1.

Respiratory Effects. No studies were located regarding respiratory effects in humans after inhalation exposure to JP-7.

TABLE 2-1. Levels of Significant Exposure to Jet Fuels/ JP-4 and JP-7 - Inhalation

Key to figure[a]	Species/ (strain)	Exposure/ duration/ frequency	System	NOAEL (mg/m3)	LOAEL Less serious (mg/m3)	LOAEL Serious (mg/m3)	Reference Chemical Form
INTERMEDIATE EXPOSURE							
Systemic							
1	Monkey (Rhesus)	6 mo 5 d/wk 6 hr/d	Hemato	5000			Air Force 1974 JP-4
			Hepatic	5000			
			Bd Wt	5000			
2	Rat (Fischer 344)	90 d 7 d/wk 24 hr/d	Hemato	1000			Air Force 1980 JP-4 (PET)
			Hepatic	1000 F	500 M (9% decreased liver weight)		
			Renal	500 M	1000 M (22% increased kidney weight)		
				1000 F			
			Bd Wt	500			
3	Rat (Fischer 344)	90 d 7 d/wk 24 hr/d	Resp	1000			Air Force 1984b JP-4 (PET)
			Hemato	1000			
			Hepatic	1000			
			Renal	1000 F	500 M (hyaline degeneration of renal tubular epithelium, renal tubular casts related to alpha-2μ-globulin nephropathy)		
			Bd Wt		500 (unspecified decreased body weight)		

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TABLE 2-1. Levels of Significant Exposure to Jet Fuels/ JP-4 and JP-7 - Inhalation (continued)

Key to figure[a]	Species/ (strain)	Exposure/ duration/ frequency	System	NOAEL (mg/m3)	LOAEL Less serious (mg/m3)	LOAEL Serious (mg/m3)	Reference Chemical Form
4	Rat (Fischer 344)	90 d 7 d/wk 24 hr/d	Hemato	1000			Air Force 1984c JP-4 (SH)
			Hepatic	500 F	1000 F (5% increased liver weight) 500 M (11% increased liver weight)		
			Renal	1000 F	500 M (19% increased kidney weight, 26% decreased urine osmolality)		
			Bd Wt	1000			
5	Rat (Fischer 344)	90 d 7 d/wk 24 hr/d	Resp	1000 M			Newton et al. 1991 JP-4 (SH)
6	Mouse (C57BL/6)	90 d 7 d/wk 24 hr/d	Resp	1000 F			Air Force 1984b JP-4 (PET)
			Hepatic		500[b] F (fatty degeneration)		
			Renal	1000 F			
7	Dog (Beagle)	8 mo 5 d/wk 6 hr/d	Resp	5000			Air Force 1974 JP-4
			Gastro	2500	5000 (emesis)		
			Hemato	5000 M 2500 F	5000 F (unspecified increased red blood cell fragility)		
			Bd Wt	5000			
8	Dog (Beagle)	90 d 7 d/wk 24 hr/d	Resp	1000			Air Force 1984b JP-4 (PET)
			Cardio	1000			
			Renal	1000			
			Other	1000			

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TABLE 2-1. Levels of Significant Exposure to Jet Fuels/ JP-4 and JP-7 - Inhalation (continued)

Key to figure[a]	Species/ (strain)	Exposure/ duration/ frequency	System	NOAEL (mg/m3)	LOAEL: Less serious (mg/m3)	LOAEL: Serious (mg/m3)	Reference Chemical Form
	Neurological						
9	Monkey (Rhesus)	6 mo 5 d/wk 6 hr/d			2500 (unspecified depressed activity)		Air Force 1974 JP-4
10	Dog (Beagle)	8 mo 5 d/wk 6 hr/d			2500 (unspecified depressed activity)		Air Force 1974 JP-4
	Reproductive						
11	Rat (F-344, S-D, Wistar, O-M)	90 d 7 d/wk 24 hr/d			1000 M (at day 90: 3% increased testis weight for Fischer 344 rats)		Air Force 1984d JP-4 (SH)

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TABLE 2-1. Levels of Significant Exposure to Jet Fuels/ JP-4 and JP-7 - Inhalation (continued)

Key to figure[a]	Species/ (strain)	Exposure/ duration/ frequency	System	NOAEL (mg/m3)	LOAEL: Less serious (mg/m3)	LOAEL: Serious (mg/m3)	Reference Chemical Form
CHRONIC EXPOSURE							
Systemic							
12	Rat (Fischer 344)	1 yr 5 d/wk 6 hr/d	Resp	750			Air Force 1991 JP-7
			Hemato	750 F	150 M (16% decreased WBC count)		
			Hepatic		150[c] (21and 29% increased alkaline phosphatase in males and females respectively, 9% increased absolute liver weight in females)		
			Renal	750 F	150 M (hyaline droplet formation, hydronephrosis,tubular mineralization and 13% increased BUN)		
			Ocular	750			
			Bd Wt		150 (unspecified decrease "throughout the study period")		
13	Rat (Fischer 344)	12 mo 5 d/wk 6 hr/d	Resp	5000			Bruner et al. 1993 JP-4
			Hemato		1000 (23 and 24% reduced mean WBC in females and males, respectively)		
			Hepatic	5000			
			Renal	1000 M 5000 F	5000 M (mild progressive nephropathies, medullary mineral deposits)		
			Bd Wt	5000			

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TABLE 2-1. Levels of Significant Exposure to Jet Fuels/ JP-4 and JP-7 - Inhalation (continued)

Key to figure[a]	Species/ (strain)	Exposure/ duration/ frequency	System	NOAEL (mg/m3)	LOAEL Less serious (mg/m3)	LOAEL Serious (mg/m3)	Reference Chemical Form
14	Rat (Fischer 344)	12 mo 5 d/wk 6 hr/d	Resp	5000			Bruner et al. 1993 JP-4
			Hepatic	5000 F	1000 M (11% decreased liver weight - 12 months post-exposure)		
			Renal		1000 (4 and 10%decreased kidney weight in males and females respectively, increased medullary mineral deposits in 14% of males - 12 months post-exposure)		
			Bd Wt	1000			
15	Mouse (C57BL/6)	1 yr 5 d/wk 6 hr/d	Hepatic	750 M	150 F (inflammation after 12-month post-exposure period)		Air Force 1991 JP-7
16	Mouse (C57BL/6)	1 yr 5 d/wk 6 hr/d	Endocr	750 M	150 F (43% increased incidence of adrenal capsular cell hyperplasia)		Air Force 1991 JP-7
17	Mouse (C57BL6)	12 mo 5 d/wk 6 hr/d	Resp		1000 (M: 38% increased nasolacrimal duct hyperplasia. F: 27% increased mild pulmonary inflammation)		Bruner et al. 1993 JP-4
			Hepatic	5000 M 1000 F	5000 F (37% increased lymphocytic inflammatory infiltrates)		
			Renal	5000			
			Bd Wt	5000			

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TABLE 2-1. Levels of Significant Exposure to Jet Fuels/ JP-4 and JP-7 - Inhalation (continued)

Key to[a] figure	Species/ (strain)	Exposure/ duration/ frequency	System	NOAEL (mg/m3)	LOAEL Less serious (mg/m3)	LOAEL Serious (mg/m3)	Reference Chemical Form
18	Mouse (C57BL6)	12 mo 5 d/wk 6 hr/d	Resp	5000			Bruner et al. 1993 JP-4
			Hepatic	5000			
			Renal	5000			
			Bd Wt	5000			
Immuno./Lymphor							
19	Rat (Fischer 344)	12 mo 5 d/wk 6 hr/d		5000 M	1000 F (24% increased spleen weight)		Bruner et al. 1993 JP-4
Reproductive							
20	Rat (Fischer 344)	12 mo 5 d/wk 6 hr/d			5000 (increased cystic degeneration of the prostate in 52% of males; increased cystic hyperplasia of the mammary glands in 35% of females - 12 months post-exposure)		Bruner et al. 1993 JP-4
21	Mouse (C57BL6)	12 mo 5 d/wk 6 hr/d		5000			Bruner et al. 1993 JP-4

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TABLE 2-1. Levels of Significant Exposure to Jet Fuels/ JP-4 and JP-7 - Inhalation (continued)

Key to figure[a]	Species/ (strain)	Exposure/ duration/ frequency	System	NOAEL (mg/m3)	LOAEL Less serious (mg/m3)	LOAEL Serious (mg/m3)	Reference Chemical Form
22	Mouse (C57BL6)	12 mo 5 d/wk 6 hr/d		5000 F	1000 M (increased testicular atrophy in 47% of males - 12 months post-exposure)		Bruner et al. 1993 JP-4

[a]The number corresponds to entries in Figure 2-1.
[b]Used to derive an intermediate inhalation minimal risk level (MRL) of 9 mg/m^3, concentration divided by an uncertainty factor of 300 (10 for use of a LOAEL, 3 for interspecies extrapolation, and 10 for human variability) and multiplied by a factor of 5.7 for converting from animal to human exposure.
[c]Used to derive a chronic inhalation MRL of 0.3 mg/m^3, concentration adjusted from intermittent to continuous dosing (150 mg/m^3 x 5 d/7 d x 6 hr/24 hr); adjusted concentration divided by an uncertainty factor of 300 (10 for use of a LOAEL, 3 for interspecies extrapolation, and 10 for human variability) and multiplied by a factor of 3.3 for converting from animal to human exposure.

Bd Wt = body weight; BUN = blood urea nitrogen; Cardio = cardiovascular; CEL = cancer effect level; d = day(s); F = female; F-344 = Fischer 344; Gastro = gastrointestinal; HCT = hematocrit; Hemato = hematological; HGB = hemoglobin; hr = hour(s); Immuno./Lymphor = immunological/lymphoreticular; JP-4 = jet propellant-4; JP-7 = jet propellant-7; LOAEL = lowest-observable-adverse-effect level; LT50 = time to 50% kill; O-M = Osborne-Mendel; M = male; MCH = mean corpuscular hemoglobin; mo = month(s); NOAEL = no-observable-adverse-effect level; PET = petroleum-derived; Resp = respiratory; SH = shale-derived; S-D = Sprague-Dawley; WBC = white blood cell; wk = week(s).

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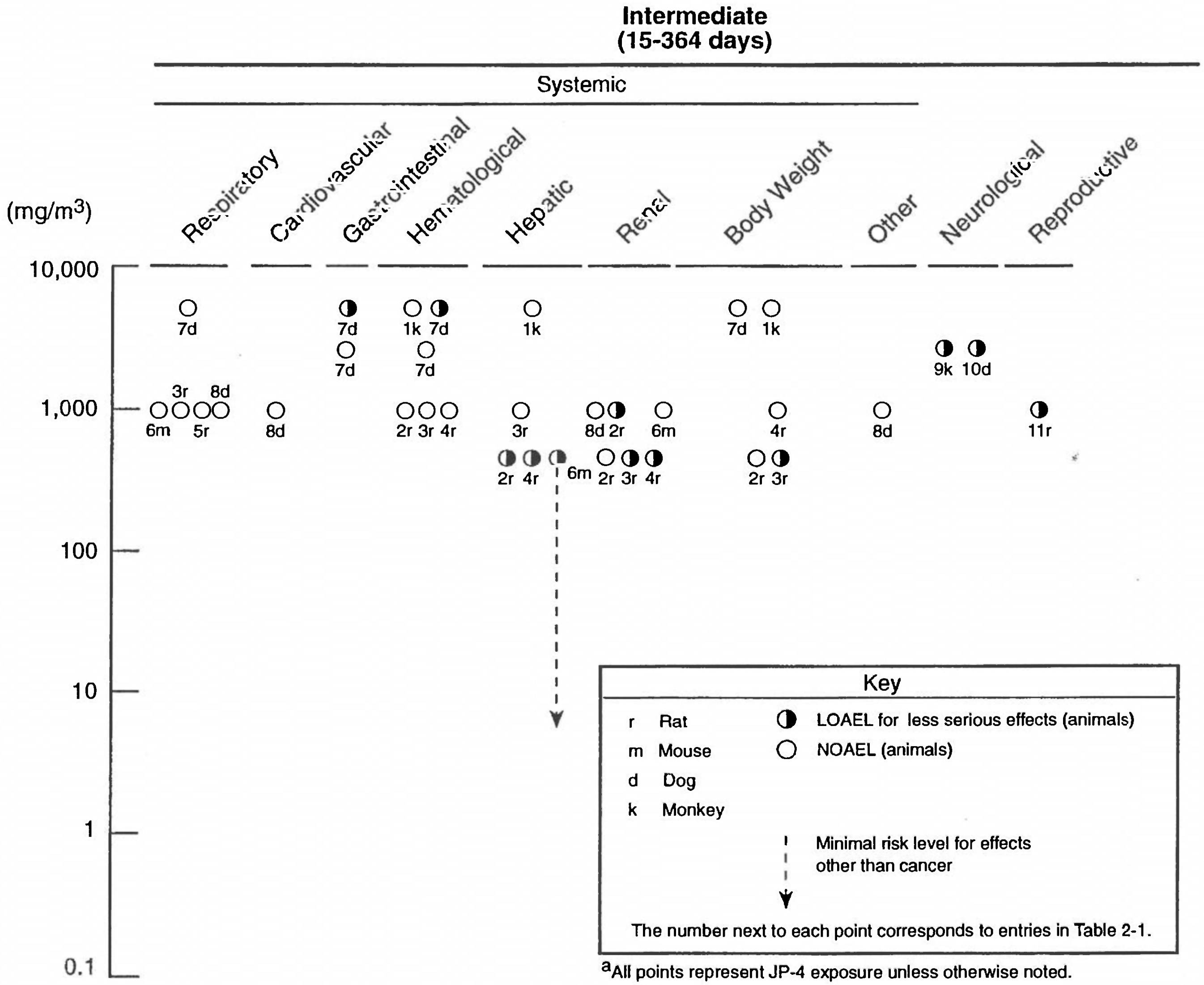
Figure 2-1. Levels of Significant Exposure to Jet Fuels[a] – Inhalation



[a]All points represent JP-4 exposure unless otherwise noted.

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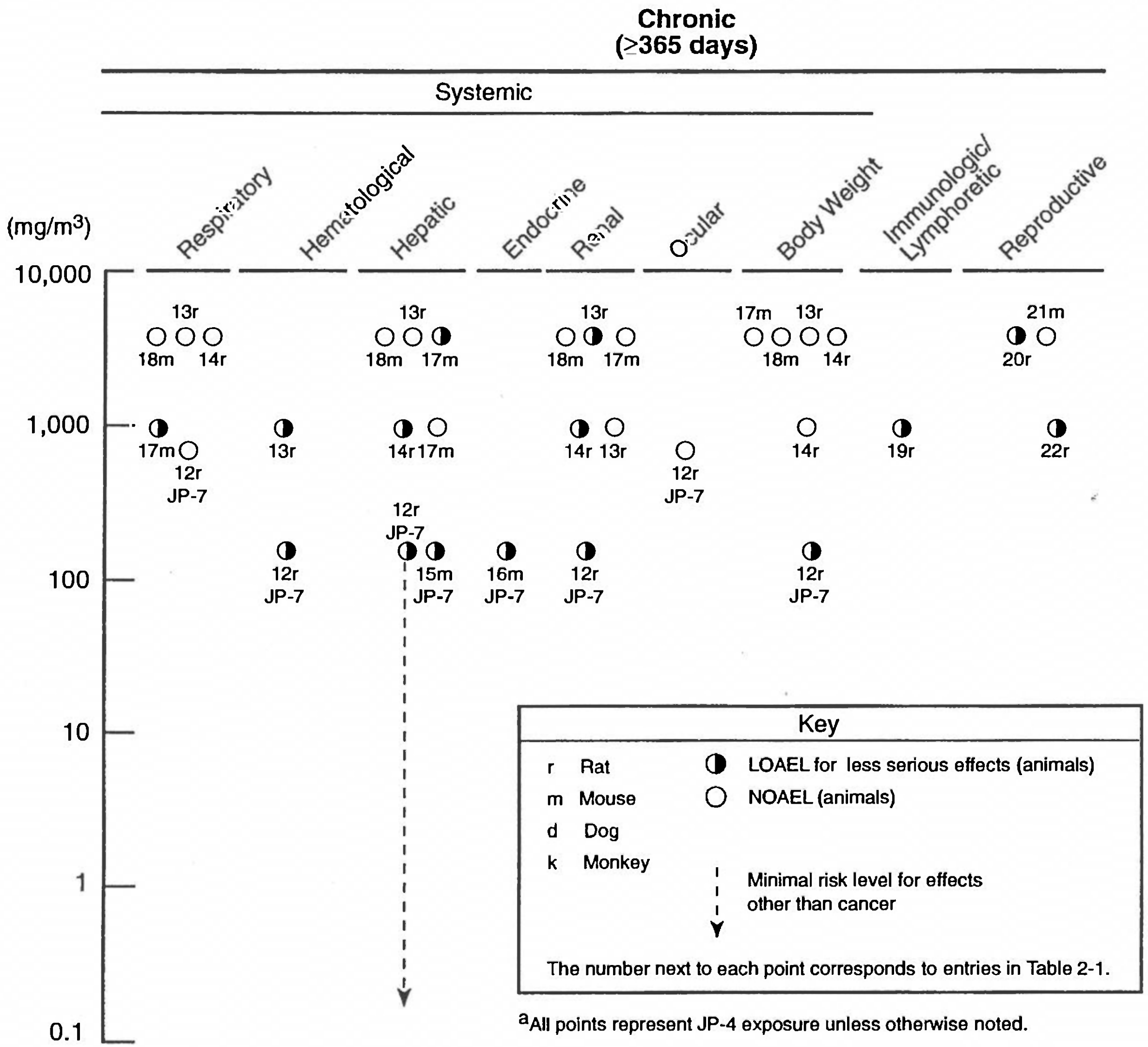
Figure 2-1. Levels of Significant Exposure to Jet Fuels[a] – Inhalation (continued)



[a]All points represent JP-4 exposure unless otherwise noted.

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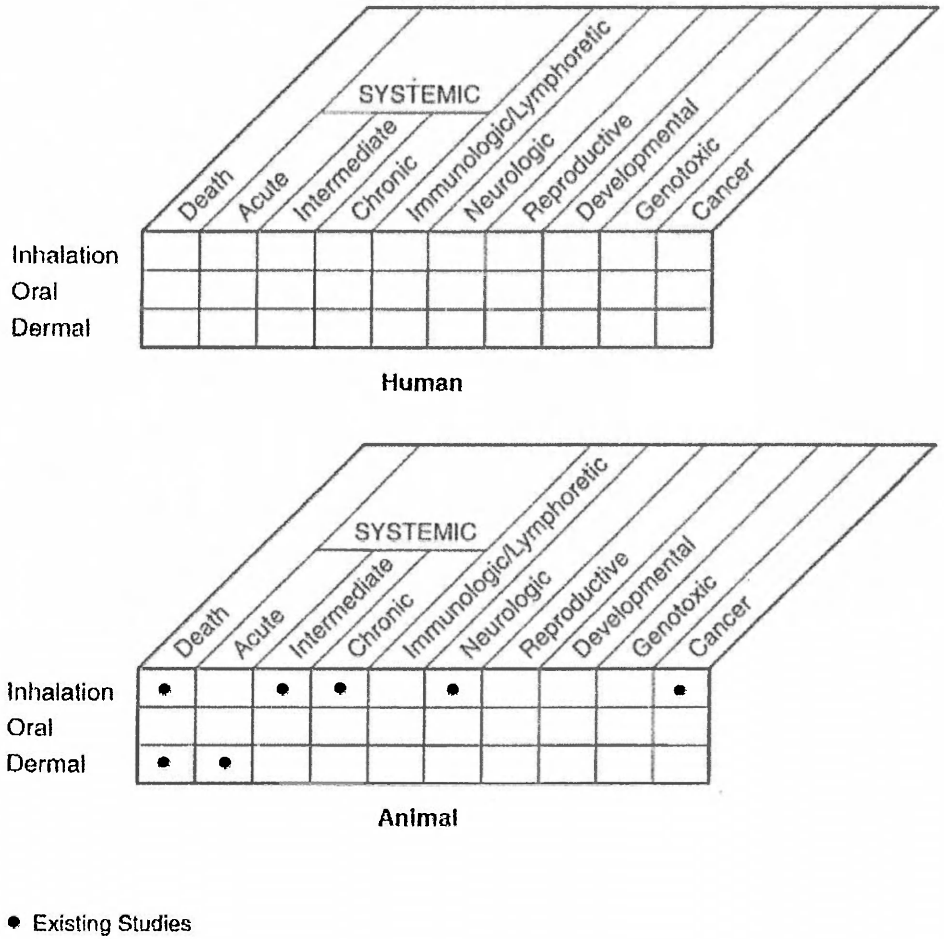

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