The Greenhouse Effect

CE 326 Principles of Environmental Engineering

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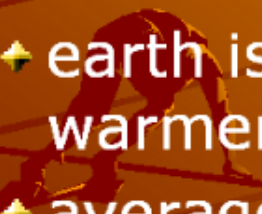
January 28, 2008

Greenhouse Effect

- **Greenhouse effect**: natural effect of the gases in earth's atmosphere to trap incident solar radiation
- earth is an average of 32 °C warmer than if no greenhouse effect
- average earth temp would be -18 °C instead of current 14 °C



Global Warming

- **Global warming**: t_____ that the accumulation of specific gaseous compounds is causing an uncontrollable increase in the earth's temperature with potentially devastating g_____ effects

What is Known

- naturally occurring greenhouse gases include w ater vapor, carbon dioxide, methane, nitrous oxide, and ozone
- concentrations of most are increasing due to a nthropogenic sources
- water vapor is the most a bundant greenhouse gas, but its concentrations are closely related to global temperatures and are relatively constant
- P eriods of high concentrations of CO_2 in past history of the Earth have been accompanied by high temperatures at the Earth's surface, and periods of low carbon dioxide had relatively low surface temperatures.

http://www.meteor.iastate.edu/gccourse/model/co2/seedsci.html

What is known

- sea level has risen 4-8 inches over the past century
- global mean surface temperatures have increased 0.25-0.5 C since the late 19th century
- Greenhouse gases have long lifetimes, ranging from 10 years for methane to about 100 for carbon dioxide to 150 years for nitrous oxide.
- Anthropogenic increases in these gases could influence the earth's climate for many centuries.
- The climate system has high inertia, primarily due to the long time scales of ocean dynamical processes.

http://www.meteor.iastate.edu/gccourse/model/co2/seedsci.html

What is known

- S ulfate particles that form from sulfur dioxide emitted primarily by the burning of coal contribute to local cooling although the magnitude is uncertain.
- Decreases of ozone in the lower stratosphere have contributed to cooling effects in that region.

http://www.meteor.iastate.edu/gccourse/model/co2/seedsci.html

What we think will happen

- the stratosphere will continue to c**ool** as CO_2 concentrations r**ise**. Ozone depletion will add to the cooling.
- water vapor in the lower troposphere (0-3 km) will increase about **6** % for every 1°C of warming. Relative humidities will stay approximately the same.
- The warming of the last c**entury** is consistent with model projections of global warming due to CO_2 modified by the regional cooling effect of sulfate particles.

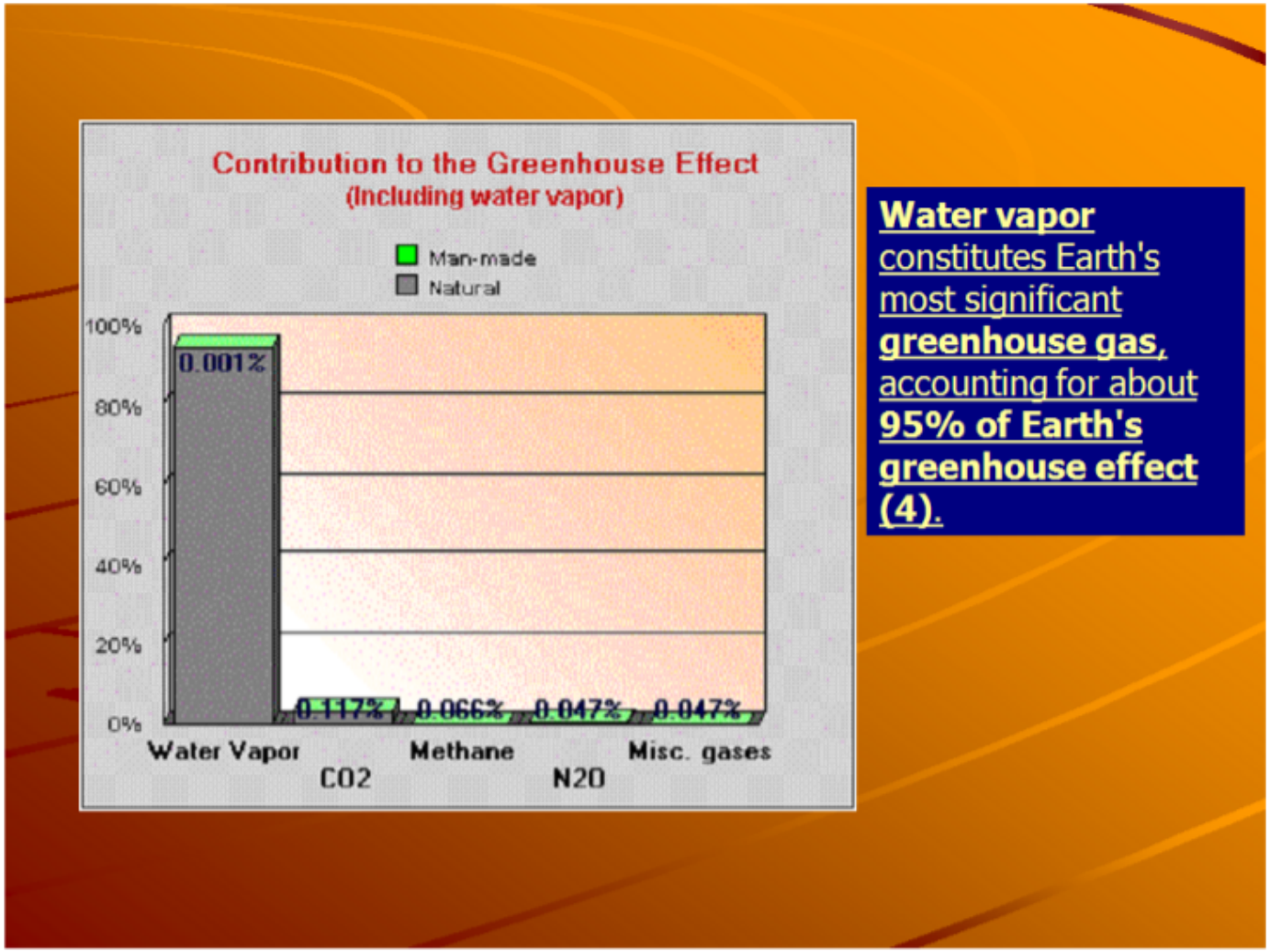
http://www.meteor.iastate.edu/gccourse/model/co2/seedsci.html

What we think will happen

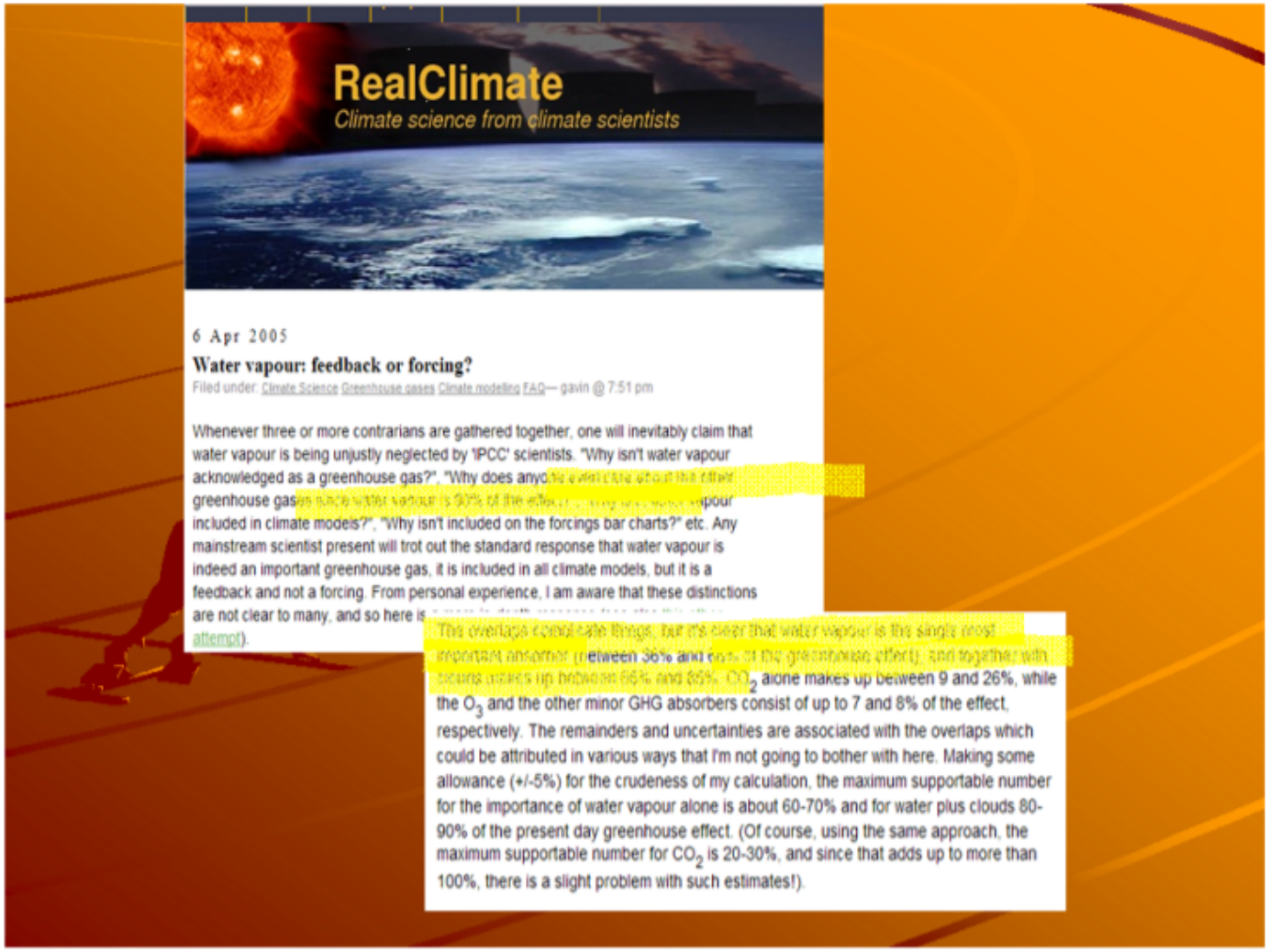
- D oubling of CO_2 over pre-industrial levels (likely to occur in the later half of the 21st century unless emissions are significantly reduced) is projected to lead to a global warming of 1.5 to 4.5°C (2 - 8°F).
- by 2100 we can expect temperature increase of 1.5 °C to 5 °C.
- Sea-level rise is most likely to be 50 (+/-25) cm by year 2100 with continued rise beyond that time highly likely. Continued high (quadrupled) CO_2 could lead to 2 +/- m rise in sea level.
- Global mean precipitation will increase at 2 (+/-0.5)% per 1°C of warming.

http://www.meteor.iastate.edu/gccourse/model/co2/seedsci.html


Is there a scientific debate over
man-made global warming?



Water vapor constitutes Earth's most significant **greenhouse gas,** accounting for about **95% of Earth's greenhouse effect (4).**


RealClimate
Climate science from climate scientists
6 Apr 2005
Water vapour: feedback or forcing?
Filed under: Climate Science Greenhouse gases Climate modelling FAQ — gavin @ 7:51 pm
Whenever three or more contrarians are gathered together, one will inevitably claim that water vapour is being unjustly neglected by 'IPCC' scientists. "Why isn't water vapour acknowledged as a greenhouse gas?", "Why does anyone ever talk about the other greenhouse gases since water vapour is 90% of the effect", "Why isn't water vapour included in climate models?", "Why isn't included on the forcings bar charts?" etc. Any mainstream scientist present will trot out the standard response that water vapour is indeed an important greenhouse gas, it is included in all climate models, but it is a feedback and not a forcing. From personal experience, I am aware that these distinctions are not clear to many, and so here is
attempt).
between 36% and
alone makes up between 9 and 26%, while the O_3 and the other minor GHG absorbers consist of up to 7 and 8% of the effect, respectively. The remainders and uncertainties are associated with the overlaps which could be attributed in various ways that I'm not going to bother with here. Making some allowance (+/-5%) for the crudeness of my calculation, the maximum supportable number for the importance of water vapour alone is about 60-70% and for water plus clouds 80-90% of the present day greenhouse effect. (Of course, using the same approach, the maximum supportable number for CO_2 is 20-30%, and since that adds up to more than 100%, there is a slight problem with such estimates!).


Water Vapour is up to 40,000 parts per million volume of air - variable - typically 10,000.
It's molecule has a greenhouse effect three times that of Carbon Dioxide.
Carbon Dioxide, at a concentration of 370 parts per million volume is, in effect, not actually a Greenhouse gas at all.
http://home.austarnet.com.au/yours/Greenhouse_Bullcrap.htm
aninconvenienttruth
A GLOBAL WARNING

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Remember Global Cooling?

Why scientists find climate change so hard to predict.

WEB EXCLUSIVE

By Jerry Adler
Updated: 5:41 p.m. ET Oct 23, 2006

Oct. 23, 2006 - In April, 1975, in an issue mostly taken up with stories about the collapse of the American-backed government of South Vietnam, NEWSWEEK published a small back-page article about a very different kind of disaster. Citing "ominous signs that the earth's weather patterns have begun to change dramatically," the magazine warned of an impending "drastic decline in food production." Political disruptions stemming from food shortages could affect "just about every nation on earth." Scientists urged governments to consider emergency action to head off the terrible threat of . . . well, if you had been following the climate-change debates at the time, you'd have known that the threat was: global cooling.

Story continues below ↓

Imaginechina (left); detail from 4/28/1975 Newsweek article

Hot and Cold: Signs of global warming at a dried-up pond in China in August 2006 (left) and a 1975 NEWSWEEK report on the threat of global cooling.

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Newsweek, April 28, 1975

SCIENCE

The Cooling World

There are ominous signs that the earth's weather patterns have begun to change dramatically and that these changes may portend a drastic decline in food production—with serious political implications for just about every nation on earth. The drop in food output could begin quite soon, perhaps only ten years from now. The regions destined to feel its impact are the great wheat-producing lands of Canada and the U.S.S.R. in the north, along with a number of marginally self-sufficient tropical areas—parts of India, Pakistan, Bangladesh, Indochina and Indonesia—where the growing season is dependent upon the rains brought by the monsoon.

The evidence in support of these predictions has now begun to accumulate so massively that meteorologists are hard-pressed to keep up with it. In England a study released last month by two

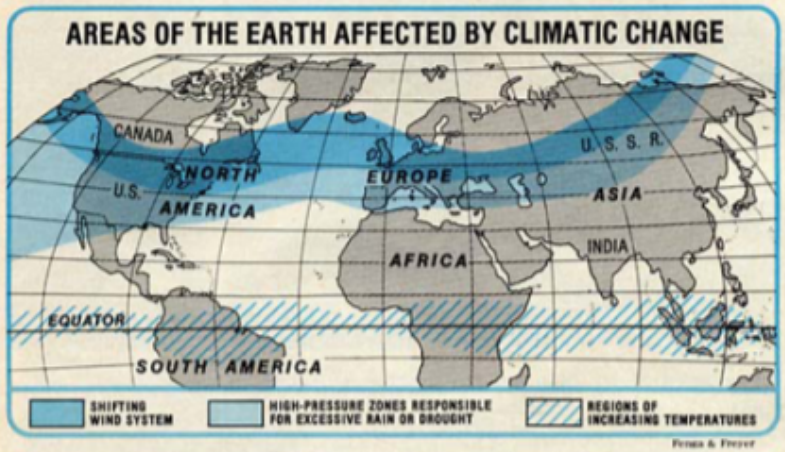
reduce agricultural productivity for the rest of the century. If the climatic change is as profound as some of the pessimists fear, the resulting famines could be catastrophic. "A major climatic change would force economic and social adjustments on a worldwide scale," warns a recent report by the National Academy of Sciences, "because the global patterns of food production and population that have evolved are implicitly dependent on the climate of the present century."

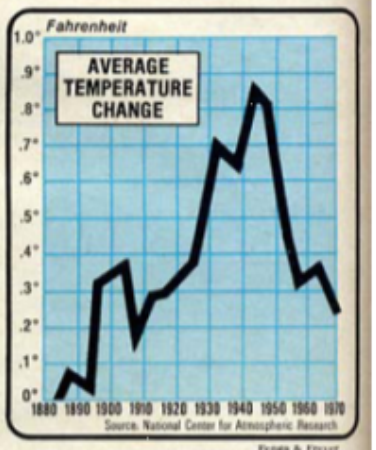
A survey completed last year by Dr. Murray Mitchell of the National Oceanic and Atmospheric Administration reveals a drop of half a degree in average ground temperatures in the Northern Hemisphere between 1945 and 1968. According to George Kukla of Columbia University, satellite photos indicated a sudden, large increase in Northern Hemisphere snow cover in the winter of 1971-72. And

ic change is at least as fragmentary as our data," concedes the National Academy of Sciences report. "Not only are the basic scientific questions largely unanswered, but in many cases we do not yet know enough to pose the key questions."

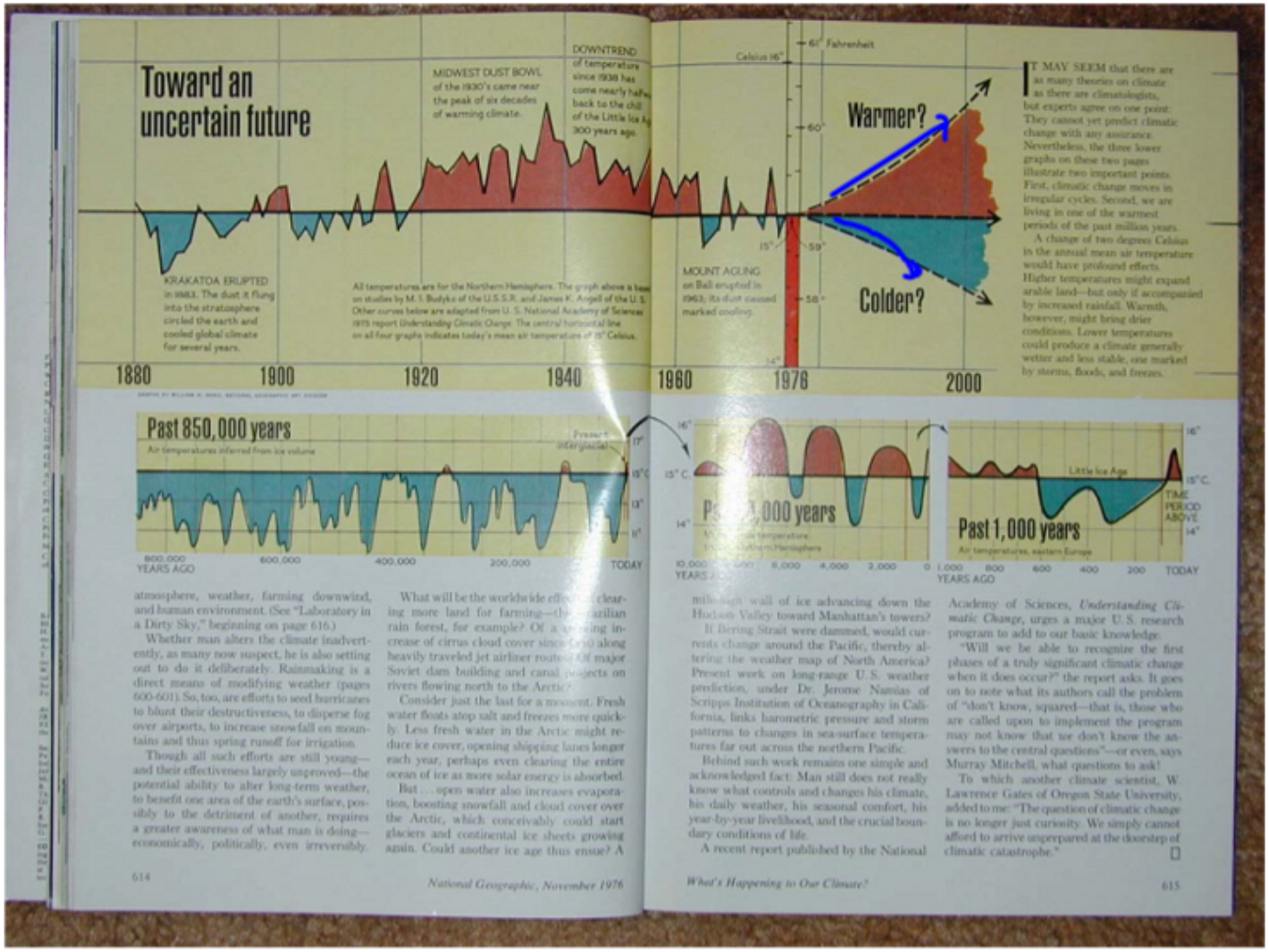
Extremes: Meteorologists think that they can forecast the short-term results of the return to the norm of the last century. They begin by noting the slight drop in over-all temperature that produces large numbers of pressure centers in the upper atmosphere. These break up the smooth flow of westerly winds over temperate areas. The stagnant air produced in this way causes an increase in extremes of local weather such as droughts, floods, extended dry spells, long freezes, delayed monsoons and even local temperature increases—all of which have a direct impact on food supplies.

"The world's food-producing system," warns Dr. James D. McQuigg of NOAA's Center for Climatic and Environmental Assessment, "is much more sensitive to





the weather variable than it was even

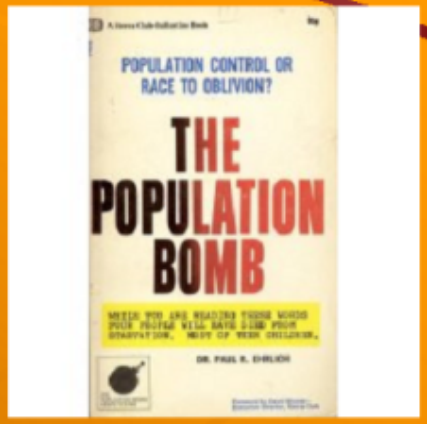

Toward an uncertain future
MIDWEST DUST BOWL of the 1930's came near the peak of six decades of warming climate.
DOWNTREND of temperature since 1938 has come nearly halfway back to the chill of the Little Ice Age 300 years ago.
KRAKATOA ERUPTED in 1883. The dust it flung into the stratosphere circled the earth and cooled global climate for several years.
All temperatures are for the Northern Hemisphere. The graph above is based on studies by M. I. Budyko of the U.S.S.R. and James K. Angell of the U. S. Other curves below are adapted from U. S. National Academy of Sciences 1975 report Understanding Climatic Change. The central horizontal line on all four graphs indicates today's mean air temperature of 15° Celsius.
1880
1900
1920
1940
1960
1976
2000
Celsius 16°
15°
14°
61° Fahrenheit
60°
59°
58°
Warmer?
Colder?
MOUNT AGUNG on Bali erupted in 1963; its dust caused marked cooling.
IT MAY SEEM that there are as many theories on climate as there are climatologists, but experts agree on one point: They cannot yet predict climatic change with any assurance. Nevertheless, the three lower graphs on these two pages illustrate two important points. First, climatic change moves in irregular cycles. Second, we are living in one of the warmest periods of the past million years.
A change of two degrees Celsius in the annual mean air temperature would have profound effects. Higher temperatures might expand arable land—but only if accompanied by increased rainfall. Warmth, however, might bring drier conditions. Lower temperatures could produce a climate generally wetter and less stable, one marked by storms, floods, and freezes.
Past 850,000 years
Air temperatures inferred from ice volume
Present interglacial
17°
15° C.
13°
11°
800,000 YEARS AGO
600,000
400,000
200,000
TODAY
16°
15° C.
14°
10,000
8,000
4,000
2,000
0
YEARS AGO
Past 1,000 years
Air temperatures, eastern Europe
Little Ice Age
TIME PERIOD ABOVE
1,000
800
600
400
200
TODAY
YEARS AGO
atmosphere, weather, farming downwind, and human environment. (See "Laboratory in a Dirty Sky," beginning on page 616.)
Whether man alters the climate inadvertently, as many now suspect, he is also setting out to do it deliberately. Rainmaking is a direct means of modifying weather (pages 600-601). So, too, are efforts to seed hurricanes to blunt their destructiveness, to disperse fog over airports, to increase snowfall on mountains and thus spring runoff for irrigation.
Though all such efforts are still young—and their effectiveness largely unproved—the potential ability to alter long-term weather, to benefit one area of the earth's surface, possibly to the detriment of another, requires a greater awareness of what man is doing—economically, politically, even irreversibly.
What will be the worldwide effect of clearing more land for farming—the Brazilian rain forest, for example? Of a seeming increase of cirrus cloud cover since 1950 along heavily traveled jet airliner routes? Of major Soviet dam building and canal projects on rivers flowing north to the Arctic?
Consider just the last for a moment. Fresh water floats atop salt and freezes more quickly. Less fresh water in the Arctic might reduce ice cover, opening shipping lanes longer each year, perhaps even clearing the entire ocean of ice as more solar energy is absorbed.
But . . . open water also increases evaporation, boosting snowfall and cloud cover over the Arctic, which conceivably could start glaciers and continental ice sheets growing again. Could another ice age thus ensue? A mile-high wall of ice advancing down the Hudson Valley toward Manhattan's towers?
If Bering Strait were dammed, would currents change around the Pacific, thereby altering the weather map of North America? Present work on long-range U.S. weather prediction, under Dr. Jerome Namias of Scripps Institution of Oceanography in California, links barometric pressure and storm patterns to changes in sea-surface temperatures far out across the northern Pacific.
Behind such work remains one simple and acknowledged fact: Man still does not really know what controls and changes his climate, his daily weather, his seasonal comfort, his year-by-year livelihood, and the crucial boundary conditions of life.
A recent report published by the National Academy of Sciences, *Understanding Climatic Change*, urges a major U.S. research program to add to our basic knowledge.
"Will we be able to recognize the first phases of a truly significant climatic change when it does occur?" the report asks. It goes on to note what its authors call the problem of "don't know, squared—that is, those who are called upon to implement the program may not know that we don't know the answers to the central questions"—or even, says Murray Mitchell, what questions to ask!
To which another climate scientist, W. Lawrence Gates of Oregon State University, added to me: "The question of climatic change is no longer just curiosity. We simply cannot afford to arrive unprepared at the doorstep of climatic catastrophe." □
614
National Geographic, November 1976
What's Happening to Our Climate?
615

Melting the ice cap was a "solution"

famines.

Climatologists are pessimistic that political leaders will take any positive action to compensate for the climatic change, or even to allay its effects. They concede that some of the more spectacular solutions proposed, such as melting the arctic ice cap by covering it with black soot or diverting arctic rivers,

Global cooling was the consensus view in the 1970's, as was a 10 year supply of oil, and the "population bomb."



The limits-to-growth crowd has predicted the end of oil since the days when this black gold was first discovered as an energy source in the mid-19th century. In the 1860s the U.S. Geological Survey forecast that there was "little or no chance" that oil would be found in Texas or California. In 1914 the Interior Department forecast that there was only a 10-year supply of oil left; in 1939 it calculated there was only a 13-year supply left, and in 1951 Interior warned that by the mid-1960s the oil wells would certainly run dry. **In the 1970s, Jimmy Carter somberly told the nation that "we could use up all of the proven reserves of oil in the entire world by the end of the next decade."**


Don’t just do something,
stand there!

Air Pollution Meteorology

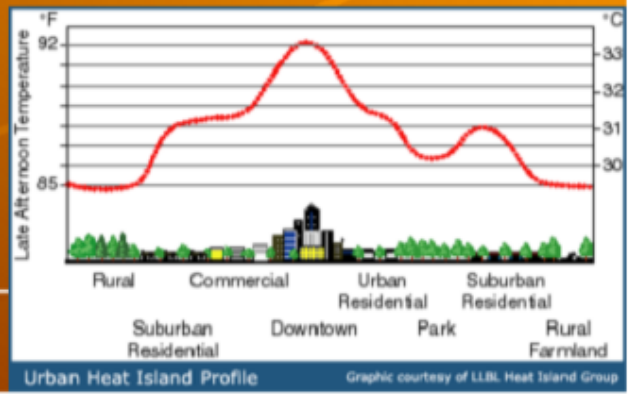
- Atmospheric Engine
  - atmospheric s tability (and weather) is a function of t empe-ature and p ressure
  - wind flows from h igh pressure areas to l ow pressure areas
  - in absence of earth's rotation, wind would be p erpendicular to constant pressure lines (i sobars) isobars
  - earth's rotation creates C oriolis effect Coriolis

Atmospheric stability

- tendency of atmosphere to r_esist_ or e_nhance_ vertical air movement is termed s_tability_
- there are three categories of stability depending on the l_apse_ r_ate_
  - rate of temperature change as a function of elevation
    - neutral – d_ry_ a_ diabatic lapse rate_
    - unstable – s_uper ad_ lapse rate
    - stable – s_ub ad_ lapse rate
      - isothermal – no change in t_emperature_ with elevation
      - i_nversion_ temperature increases with elevation

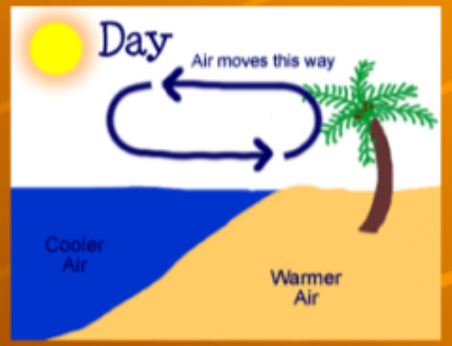
Terrain Effects

- Heat Island Effect
  - mass of material that absorbs and emits heat at a greater rate than surrounding area
  - stability over heat islands is less
    - good for ground level sources
    - bad for tall stack



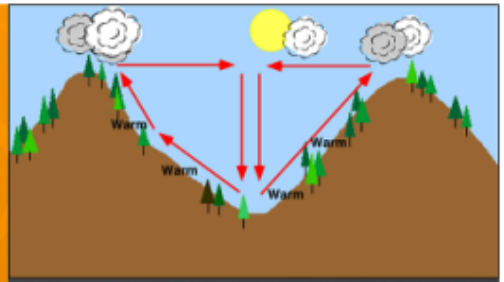
Land/Sea Breeze

- land c<u>ools</u> more rapidly at night than sea
  - l<u>and</u> breeze
- land h<u>eats</u> faster during day
  - s<u>ea</u> b<u>reeze</u>



Valleys

- valleys at an a cute angle to the prevailing wind will direct a portion of wind into the valley
- valleys oriented in the north-south direction are more susceptible to inversions than east-west direction
- during daytime sun heats valley floor
  - v alley breeze
- during night
  - h ill breeze
- early day
  - i nversion impossible



Jan 28-9:56 AM

Air Pollution Control Devices

- **A** bsorption tower
- **B** aghouse
- **C** yclone Separator
- a**D** sorption Bed
- **E** lectrostatic precipitator
- **V** enturi scrubber

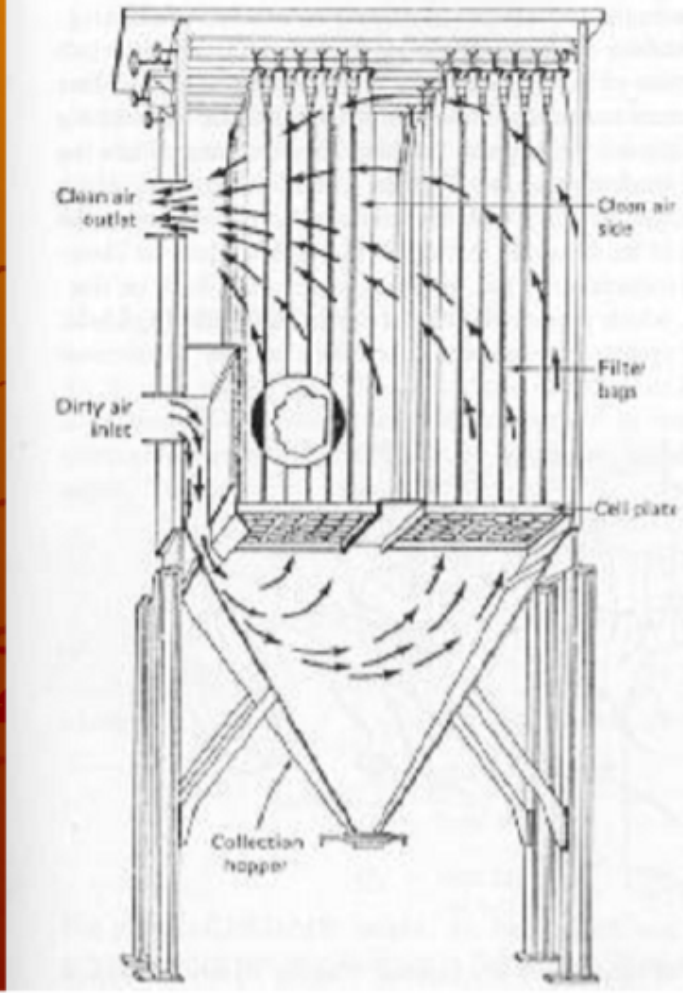
Air Pollution Control Devices

- **Absorption** Tower (Packed Bed, Spray Tower, Wet Scrubber)
  - Diffusion of the pollutant gas to the surface of the liquid
  - Transfer across the gas/liquid interface (dissolution)
  - Diffusion of the dissolved gas away from the interface into the liquid
  - Henry's law: $PA = C$

    $\mathbf{P = HC_l}$
  - where: P = equilibrium partial pressure of gas, kPa, H= Henry's law constant, $kPa \cdot m^3/g$ and C_l = concentration of pollutant gas in liquid phase, g/m3
  - want to maximize gas liquid contact by maximizing surface area
  - efficiency will be limited by the solubility of the pollutant

Baghouse

- same principle as the h ome v acuum c leaner
- bags are cleaned periodically as the p ressure d rop across the bag becomes excessive (approximately every 2 hours)
  - cleaned by mechanical r apping (used for shake-deflate design)
  - cleaned by h igh p ressure air jets (used for pulse jet design)
- must be a d ry gas stream
- potential f ire hazard
- bag "r ipen " with time
  - develops a fine mat which helps to screen out particles
- for p articulate removal, or used in conjunction with F lue G as D esulfurization (FGD) applications



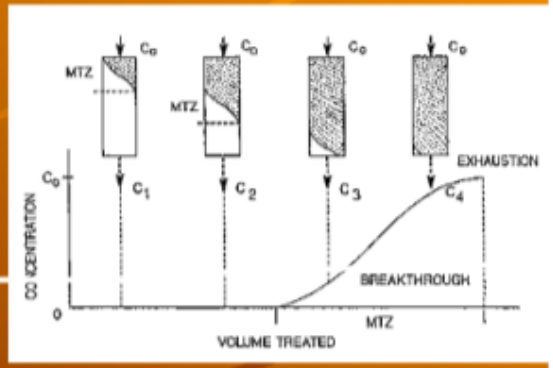
Typical Bag of Singed Polyester

Cyclone Separator

- used for particulates larger than 10 µm
- gas stream is accelerated through a spiral motion, centrifugal force moves heavier particles out and down
- as the diameter of the cyclone is reduced, the efficiency increases (as does the pressure drop)
- use of multiple tubes in parallel (multiclones) improves efficiency

Adsorption Bed

- surface phenomena
- physical or chemical bond with the surface
- adsorbents: activated carbon, activated alumina, silica gel, and others
- 1 ounce of activated carbon has a surface area of 5-10 acres
- bed must be regenerated prior to breakthrough



Electrostatic Precipitator

- wire in tube or wire and plate configurations
- wet or dry, wet cleaned by water spray, dry by rapping, can be cleaned while in service
- corona wire imparts an electrical charge (neg), particles are attracted to charged (pos) collecting plates
- high particulate removal efficiencies possible

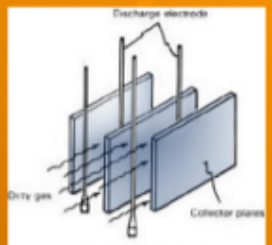
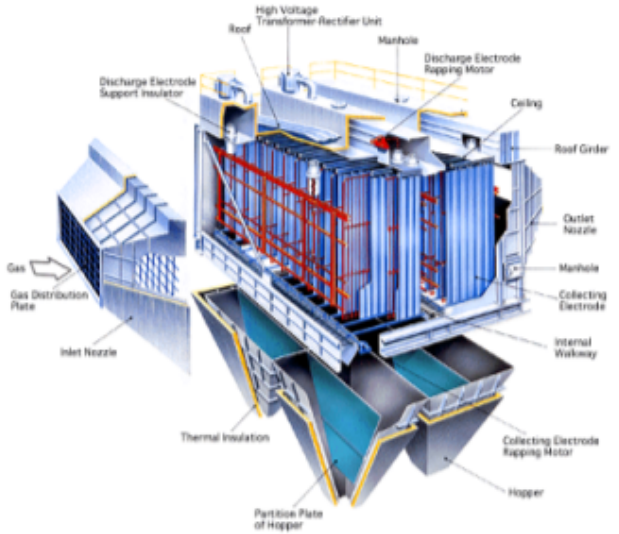
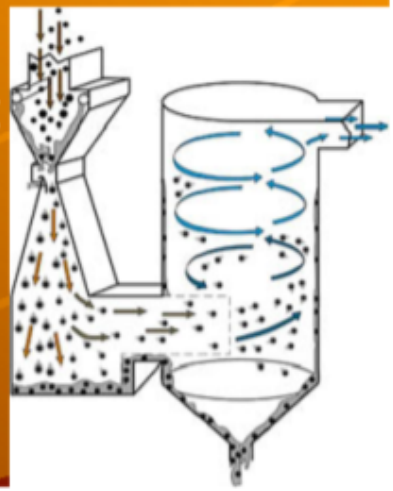


Plate-Type Precipitator

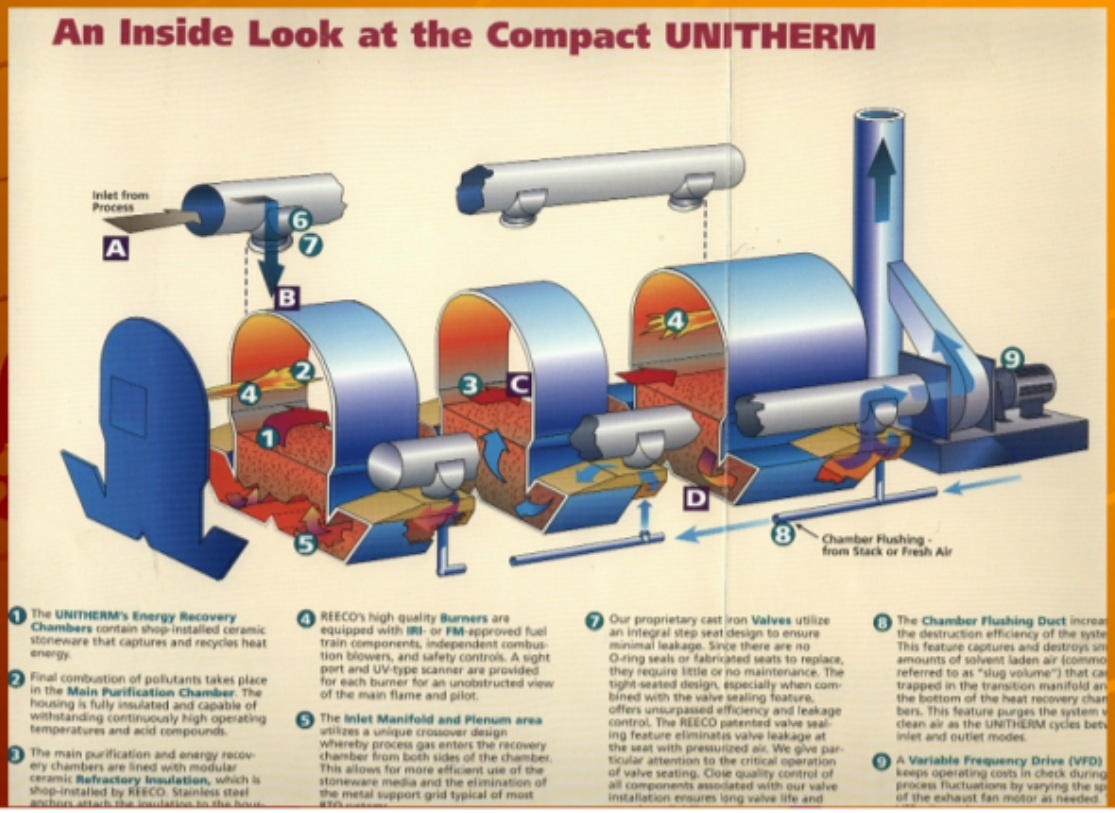


Venturi Scrubber

- velocity of gas is a ccelerated by a factor of four in the throat section where nozzles inject water or solution
- high velocity causes a tomization of liquid
- pressure drop following the throat section creates a lot of turbulence resulting in good intermixing
- requires s eparator (e.g., cyclone) following venturi to collect particles and liquid



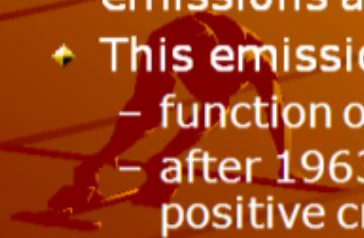
Thermal Incineration




Air Pollution Control
Devices: Mobile Sources

Automotive Emissions

- M_____ sources contribute approximately 60% of total air pollution (78% of CO, 47% of NO_X, 44% of total hydrocarbons, 5% of particulates, and 2% of SO_X
- 20 to 40% of the automobile's total hydrocarbon emissions are from the crankcase.
- This emission is called b_____.
  - function of s____
  - after 1963 all vehicles are required to have a positive crankcase ventilation (PCV) valve
  - the PCV valve opens up more at h_____ speeds to allow more crankcase fumes to be sucked into the intake manifold

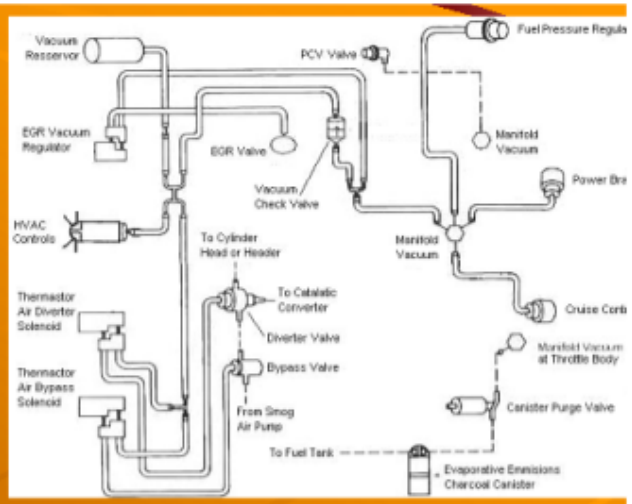


Fuel tank e_____

- As the fuel tank warms, the vapors in the headspace are exhausted through the vent line.
  - activated carbon canister
  - vent the fuel tank to the crankcase

Carburetor Losses

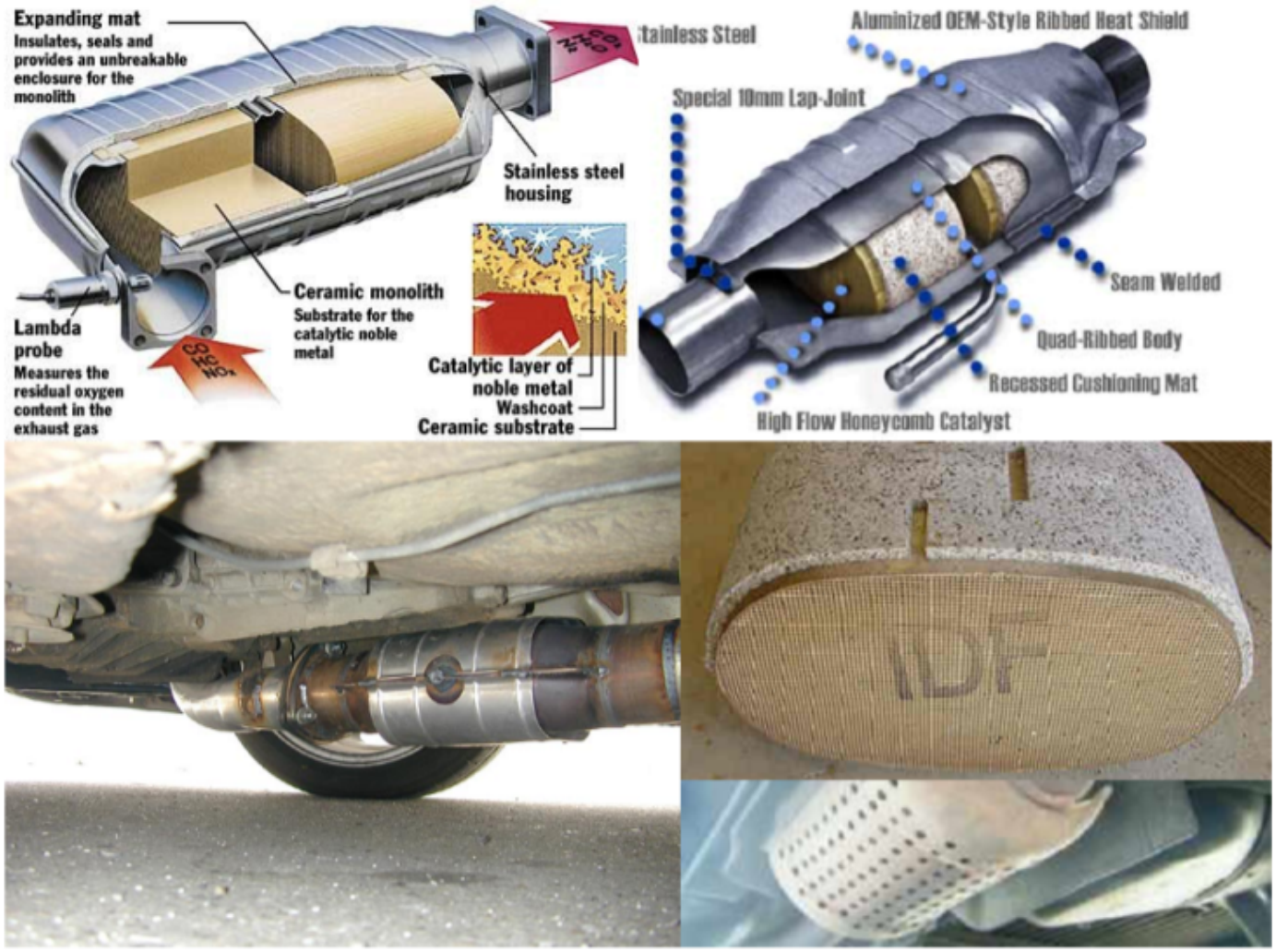
- After the engine is shut off, the gas in the float valve evaporates to the atmosphere.
- This is called h__ s____
  - activated carbon canister
  - vent to the crankcase



Engine Exhaust.

- E_____ modifications
- F_____ system modifications
- E_____ system modifications:
  - catalytic converter for NO_X and HC control
  - platinum-rhodium or platinum-palladium catalyst - requires temp of 350°C (660°F)

$$NO + CO + HC \rightarrow N_2 + CO_2 + H_2O$$


Expanding mat
Insulates, seals and provides an unbreakable enclosure for the monolith
Stainless steel housing
Ceramic monolith
Substrate for the catalytic noble metal
Lambda probe
Measures the residual oxygen content in the exhaust gas
Catalytic layer of noble metal
Washcoat
Ceramic substrate
Aluminized OEM-Style Ribbed Heat Shield
Special 10mm Lap-Joint
Seam Welded
Quad-Ribbed Body
Recessed Cushioning Mat
High Flow Honeycomb Catalyst

Diagnosing a Damaged Converter

Shell or Air Tube Damage

1 Scratched or Dented Shell

1 Cracked Neck or Shell

1 Broken Air Tube

Shell Discoloration

2345 Overall Shell Discoloration

2345 Shell Discoloration at Outlet (with Air)

Substrate Damage

24 Carbon Deposits

245 Clogged

12345 Cracked/Broken

12345 Melted/Disintegrated

Check for:

1. Physical Damage- Installation Errors, Metal Fatigue, Low Hanging Exhaust System, Broken Hanger, Brackets, Engine Mounts, Transmission Mounts, Manifold Studs, Spring Bolts, Poor Manufacturing or Inferior Materials

2. Rich Fuel Mixture- Oxygen Sensor, ECT, TPS, Spark Plugs, Ignition System, Air Filter, ECM, Engine Operating System Modifications

3. Excessive Heat- Diverter Valve, Air Injection System, Vehicle or Trailer Overload, Exhaust System Restrictions

4. Mechanical/Electrical Failures- Head Gasket, Intake Gasket, Oil in Exhaust or Fuel, Transmission Modular Failure, Piston Rings, Valve Guides, Air Injection Tube

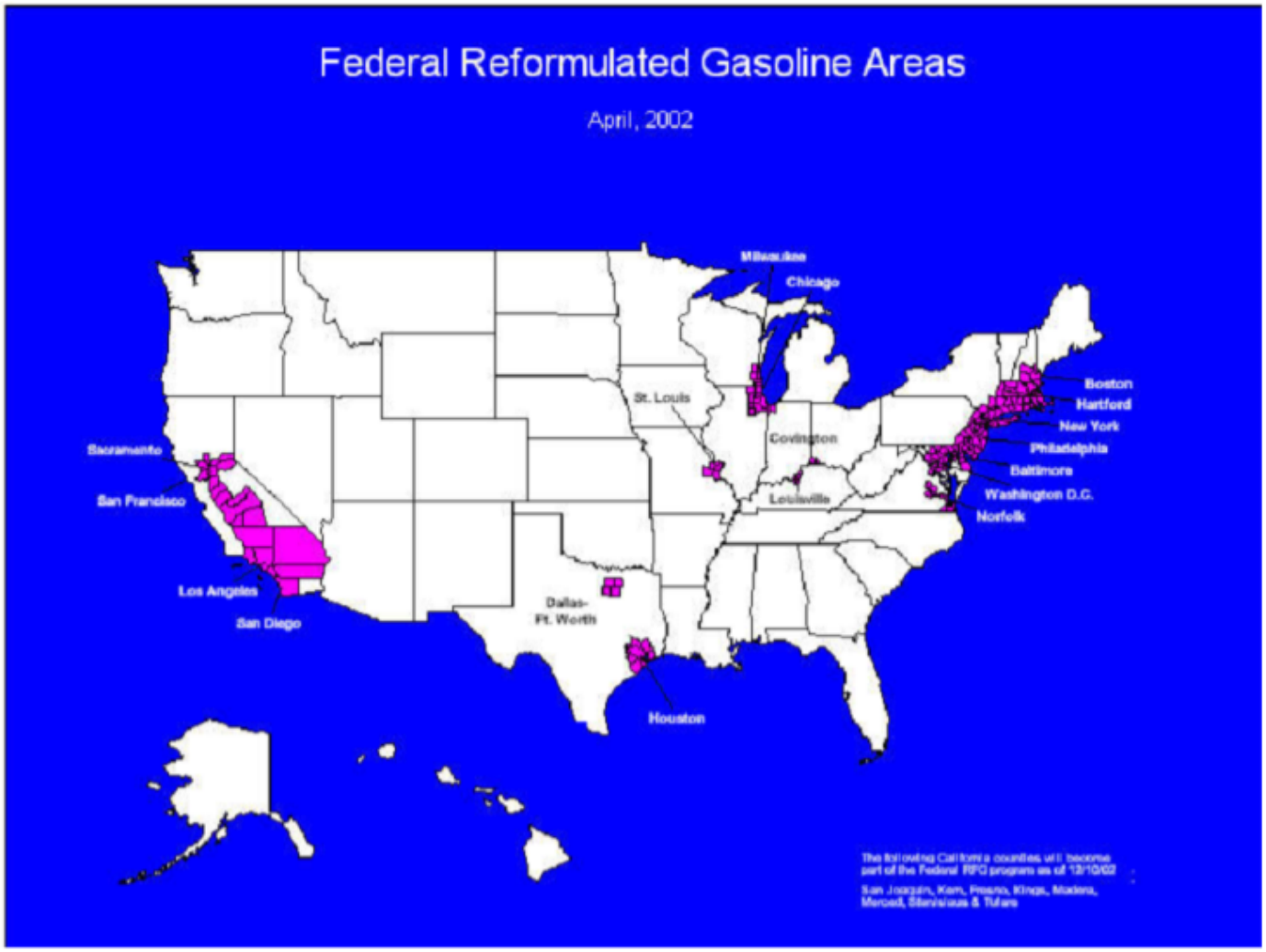
5. Fuel Contamination- Non Sensor-Safe Gas Additives, Non Sensor-Safe RTV used in engine repairs, Anti-Freeze, Poor Quality Gasoline, Fuels with High Sulfur Content

Reformulated Gasoline

- 1990 Clean Air Act Amendments had two performance targets for reformulated gasoline:
  - 15% r_____ in VOCs
  - 15% reduction in a___ t_____ (e.g., benzene)

Reformulated Gasoline

- one third of U.S. uses r_____ gasoline
- Congress mandated that reformulated fuel contains 2% o_____


Federal Reformulated Gasoline Areas
April, 2002
Milwaukee
Chicago
St. Louis
Covington
Louisville
Sacramento
San Francisco
Los Angeles
San Diego
Dallas-
Ft. Worth
Houston
Boston
Hartford
New York
Philadelphia
Baltimore
Washington D.C.
Norfolk

Common Oxygenates

- M_____
- E_____
  - fermented from c_____
- MTBE (methyl tertiary butyl ether) derived from natural gas and c_____
- ETBE (ethyl tertiary butyl ether) derived from _____

A Renewable Fuel Standard