FOIA Number: 2012-0769-F

FOIA MARKER

This is not a textual record. This is used as an administrative marker by the William J. Clinton Presidential Library Staff.

Collection/Record Group: Clinton Presidential Records

Subgroup/Office of Origin: Council on Environmental Quality

Series/Staff Member: Kathleen (Katie) McGinty

Subseries:

OA/ID Number: 2613

FolderID:

Folder Title:
Hearing - CFCs [Chlorofluorocarbons], Strong Ozone February 23, 1989

Stack:	Row:	Section:	Shelf:	Position:
S	61	5	6	2

And they agreed that when and if there is a test capable of detecting 95% of the carriers, it should be offered to everyone of reproductive age, perhaps 100 million people in the United States. Even then, they said, screening should only begin if a counseling program for education is in place.

But what happens if the test is never able to detect more than, say, 80 or 85% of the carriers? Should it be denied to the large number of couples who could nonetheless be helped? Hopkins geneticist Neil Holtzman, for one, is not so sure. Even now, with today's limited test, it is a tricky call, he says. "The problem with not screening with a 75% test is we miss the opportunity to reduce the disease in 50% of those affected." Cystic fibrosis is now the most common lethal genetic disease, affecting 1 in 2500 newborns.

Robert Williamson of St. Mary's Hospital Medical School in London agrees with Holtzman: "We have to learn how to deliver it to the 50 to 60% of the population who can benefit. I don't think we have a choice."

Others, like Michael Kaback, president-elect of the American Society of Human Genetics and chairman of the pediatrics department at the University of California, San Diego, Medical School, fear that screening with an imperfect test will do more harm than good, especially for those couples who receive inconclusive results. For now, if one partner is positive and one negative, there is no way to tell if the negative one actually does carry the disease gene, but with one of the as yet unidentified mutations. With today's test, 1 in 15 couples will be left in this genetic limbo, and Kaback suspects their anxiety will be tremendous and that some may even end up aborting healthy fetuses.

After grappling with the issue for a day and a half, the NIH panel reached no conclusion on what to do if trapped in this murky middle ground. Nevertheless, they managed to agree on some guidelines for population screening, if and when it comes about: that it should be voluntary and confidential; that it should be available to all who want it, though they advise against testing newborns and children; that informed consent be required; and that laboratory quality assurance begin immediately. They put the onus on health care providers to ensure that adequate education and counseling are available before they offer testing.

The group also recognized that the demand for testing is likely to continue to grow, even if a near perfect test can never be developed. Consequently, they called for pilot programs, to start right away, to determine how best to deliver a cystic fibrosis test and to measure just how much anxiety it produces. ■ LESLIE ROBERTS

Ozone Destruction Closer to Home

Researchers appear to have forged another link in the chain connecting man-made chlorofluorocarbons (CFCs) to losses of protective ozone over the populous mid-latitudes of the Northern Hemisphere. From Oslo to New Orleans, the ozone screen has thinned about 5% during the winter months of the past 10 years. The question: Is the ozone being destroyed by CFCs, in which case things could get worse, or are less sinister, natural variations behind the decline?

The finger of suspicion pointed to the CFCs a year ago when an airborne expedition probing the Arctic stratosphere found an abundance of ozone-destroying chlorine from CFCs (*Science*, 24 February 1989, p. 1007). But expedition researchers had their hands full showing that the chlorine was actually destroying the Arctic ozone. Now it may have finally been caught in the act.

The first direct evidence against CFCs as the culprit comes in a series of papers published in this month's *Geophysical Research Letters*, a special issue devoted to results from last year's expedition. As summarized in a prologue by atmospheric physicist Richard Turco of the University of California, Los Angeles, and others, the papers show that "the initial phases of a widespread ozone depletion apparently were observed."

The Arctic losses are a far cry from those seen every October in the Antarctic ozone hole, however. In the Antarctic, as much as half of all the stratosphere's ozone has been destroyed in some years, with the losses reaching more than 95% at some altitudes. Over the Arctic, total ozone destruction probably did not exceed a few percent and the hardest hit layers, those at and just above 20 kilometers, might have lost only 15 to 20% of their ozone.

Pinning down such small losses was not easy. For example, during the 39 days when the 1989 Airborne Arctic Stratospheric Expedition, as it is officially known, was collecting data, ozone concentrations within the 3000-kilometer-wide vortex of winds that swirl around the Arctic stratosphere actually increased below 20 kilometers as high-altitude, ozone-rich air sank into the vortex. So the challenge was to see whether the ozone increase was less than it should have been.

Participants in the Arctic expedition approached this problem by using the concentration of nitrous oxide, a relatively stable gas, as a benchmark against which to measure any loss of ozone. By determining the relative ozone and nitrous oxide concentrations, a multi-institutional group headed by atmospheric physicist Mark Schoeberl of NASA's Goddard Space Flight Center in Greenbelt, Maryland, found an ozone loss at around 20 kilometers of 15 ± 10% (95% confidence limits) during the expedition.

There was another detection of apparent ozone destruction, this one by a group headed by Edward Browell of NASA's Langley Research Center in Hampton, Virginia. Browell's group detected two patches of air that had up to 17% less ozone than the surrounding air. The nitrous oxide data again seemed to require chemical destruction of ozone. In addition, the altitude range of the patches, 17 to 23 kilometers, coincided with that of the polar stratospheric clouds. In the Antarctic ozone hole, these icy clouds catalyze the production of ozone-destroying chlorine. The coincidence of ozone loss and clouds in the Arctic implies the same may be happening there.

Despite this evidence, there are still doubters, but the link between CFCs and ozone loss was buttressed by calculations by three different groups of the amount of ozone that should have disappeared during the expedition, given the chemical state of the atmosphere at its start. Although the groups all used different modeling approaches, the results agreed "quite well with the limited observations of actual Arctic ozone variations," note the authors of the special issue's prologue.

Now that new evidence has been found that CFC-derived chlorine is destroying ozone within the Arctic vortex, the next step is to find out whether the Arctic vortex is exporting ozone-depleted air and ozone-destroying chlorine to the mid-latitudes. Such atmospheric transport could be behind the decreased wintertime ozone there. Making this connection will be particularly difficult, however, and politicians considering whether to decrease ozone destruction by further reductions of CFC emissions will probably have to settle for less than a perfect chain of cause and effect. ■ RICHARD A. KERR

Large Shifts Found in the Temperature of the Atmosphere

But scientists see no evidence of global warming in the 80's

By DAVID L. WHEELER

Scientists conducting a study of global temperatures using earth-orbiting satellites said last week that they had discovered dramatic weekly fluctuations in the atmosphere's heating and cooling, but no evidence of a global-warming trend in the 1980's.

In the March 30 issue of *Science*, John R. Christy, a research scientist at the University of Alabama at Huntsville, and Roy W. Spencer, a scientist at the National Aeronautics and Space Administration's Marshall Space Flight Center, said they had used satellite-based measurements of microwave radiation emitted by oxygen molecules to determine atmospheric temperatures from 1979 to 1988.

Microwave Radiation Measured

The oxygen molecules are spread evenly throughout the atmosphere and emit faint microwave radiation that can be used by satellite instruments to infer atmospheric temperatures.

In the study, the scientists determined average temperatures for a layer of the atmosphere from the surface to an altitude of 10 kilometers—about 6 miles.

They found that average global temperatures can go up or down by almost an entire degree on the Fahrenheit scale in two weeks.

That is the same amount of change that some scientists are arguing has been caused over the last century by the emissions of man-made "greenhouse gases," like carbon dioxide.

But the scientists who conducted the

Continued on Page A13

Shifts Found in the Atmosphere's Temperature

Continued From Page A7

new study said it did not disprove that the earth might be warming up.

"If you're just looking at a 10-year piece of a 150-year-old puzzle, you're not necessarily going to see a long-term climate trend," said Mr. Christy in an interview.

The satellite-based microwave method has been used since 1979 to obtain information for weather forecasting. But the data were archived and no one thought to use them to study climate trends until last year, Mr. Christy said.

Using the satellite instruments in climate research could make it easier to monitor changes caused by human activity, the scientists said in their report. Disputes over the accuracy of land- and ocean-temperature measurements have been at the center of the debate over whether global warming is occurring.

The new method, Mr. Christy said, is extremely accurate and "takes the temperature of a huge volume of the atmosphere."

"It cannot be affected by the kind of shelter a thermometer is in or whether it is next to a parking lot," he added. "This is a truly global measure." ■

Satellites Find No Evidence of Global Warming

Associated Press

Ten years of temperature measurements by weather satellites have failed to find any evidence of global warming from the greenhouse effect, scientists said in a report published today, but they added it will take at least another decade of measurements to draw a firm conclusion.

The data, collected from 1979 through 1988 by the TIROS-N weather satellites, proved that the atmosphere's temperature can be measured accurately by instruments probing from space, two scientists say in a paper in the journal Science.

"We found that the Earth's atmosphere goes through fairly large year-to-year changes in temperature and over that 10-year period we saw no long-term warming or cooling trend," said Roy W. Spencer of the Marshall Space Flight Center in Huntsville, Ala.

Spencer's co-investigator, John R. Christy of the University of Alabama, Huntsville, said there were temperature swings "that can be quite dramatic" during the decade, but, on a global basis, the thermal changes tended to even out.

"The northern hemisphere goes up slightly during those 10 years and the southern hemisphere goes down slightly," said Christy. "The net effect for the globe is basically zero."

Conventional temperature measurements have found the 1980s to have been the warmest decade on record but also do not show a strong warming trend within the decade.

Detecting a climate trend from space, the scientists said, will take at least another decade of satellite measurements.

"There is no guarantee that if you take a 10-year segment out of a long time, that you'll get the overall trend," said Christy. "The data cannot be used to say we've got an enhanced greenhouse effect."

Christy said the findings "are enough to tantalize us. . . but this is just a start" and satellite measurements are continuing.

"By the turn of the century, we should see a trend," said the scientist.

212-678-5619 5528 Labadorf
J.H. 201-447-0570

SCIENCE paper --- amazed that SCIENCE published w/o proper refereeing -- its good paper -- important that they can msr T from satellites...

but, w/ only 10 yrs of data shouldn't say that they observed no warming --- can't observe any trend over 10 yrs --- if change it to 5 or 11 yrs, trend & enormity -- that statement shouldn't be there...

...also they use low to mid-troposphere
T's... not ground T's ~

STATEMENT OF SENATOR ALBERT GORE

HEARING ON ARCTIC AND ANTARCTIC OZONE DEPLETION

SENATE SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

FEBRUARY 23, 1989

Let me start this morning by welcoming our guests and by expressing to them our appreciation for their testimony.

The groundbreaking work of these scientists from the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration must be reflected in our policy and, in no small way, in our very way of life. The business and industry representatives here today are on the front lines of this real-world battle.

These scientists used the most complicated instruments, the most sophisticated measuring devices to examine, what for many Americans, is a something someone else can worry about. For most families, stratospheric ozone is not nearly as pressing a concern as the mortgage payment. So maybe it's not surprising that the first question the scientists faced at a news conference where they discussed their findings, was from a

reporter looking for plain language explanations. She was speaking for a large portion of the public.

There are compelling reasons to turn this disinterest in activism. For example, there are warnings of severe economic and social disruption in the coming decade -- in the 1990s -- unless we move now to reverse the deterioration of our environment. Ozone depletion is a key factor in the warnings.

Destruction of the earth's protective ozone shield in the upper atmosphere will mean lost protection from the sun's most damaging rays and an increase in skin cancers. Estimates are that for every one percent depletion of the ozone layer, there will be a two percent increase in the incidence of skin cancer. Worldwide, some 100,000 people each year die from skin cancer. Since 1969, in the U.S. alone, ozone concentrations have decreased two to three percent. The mathematics are deadly.

Destruction of the earth's protective ozone threatens thousands of plants and crops in ways the scientists have not even fully measured and already has resulted in damage to the most basic organisms at the bottom of our food chain, simple vegetation in the Antarctic, for example, that sustains the smallest fish to the largest whale.

The scientists tell us we have a problem now. The hole in the upper ozone above Antarctica is the size of the continental United States. Conditions at the Arctic present a virtual time bomb that could cause similar problems. We know what's punching these holes -- chloroflourocarbons. We've put them up there with aerosal sprays, air conditioners, refridgerators, styrofoam. The sad truth is that everything we've dumped into our environment hasn't even yet reached the upper atmosphere.

Between today and the year 2000, the quantity of chemicals in our upper atmophere will have doubled. If we think we have a problem now, ten years from now, we will have four times as big a problem in the Arctic and Antarctic. Stated as simply as possible, for that plain-language reporter and others, this is one of the most serious environmental threats our planet faces.

Importantly, however, this is a challenge we can meet. It may mean changes in our refrigerators, different types of airconditioners in our cars. It may mean we can no longer go to the store and buy freon off the shelf.
But the fact is, we know what causes this problem: CFCs. And, we

know that reducing our consumption of these chemicals will reduce the environmental risk.

In the coming month, this hearing will be followed by another to focus on the impacts of ozone depletion and the policy responses needed to stimulate international cooperation. Today, I and my colleagues, are eager to disuss the findings of the most recent Arctic research and the private sector progress in developing alternatives to CFCs.

There must be a marriage between the scientists and the policy makers. That's the idea behind legislation I recently introduced, S. 201, which would, among other things, mandate a five year phase out of CFCs. We can't wait any longer to address this problem. The Montreal Protocol, which the Senate ratified last year, put in place international limits on CFC production. But a 50 percent reduction by 1999, as the protocol requires, is too little, too late.

The scientists who have come here today are our first defense against global environmental threats like ozone depletion. Recognizing what is happening to our planet will show us what measures we must take to halt the damage. We need a broad, international effort to monitor and understand the earth,

so that we can respond wisely to the global environmental crisis -- from ozone depletion and global warming to deforestation and acid rain.

##

REMARKS OF

SENATOR ALBERT GORE, JR.

TO THE

LONDON CONFERENCE ON SAVING THE OZONE LAYER

LONDON, MARCH 5-7, 1989

-

Prime Minister Thatcher, distinguished delegates, ladies and gentlemen. I am honored to have this opportunity to address this most important conference. Our actions here this weekend will be heard around the world for some time to come.

The nations represented here today are about to take brave and courageous steps to phase out and replace ozone-eating chlorofluorocarbons. But the most important consequence of our work may be to show the whole world that the global environment demands our immediate attention and stewardship. The message we must take home from London is that preserving the world environment is now mankind's greatest challenge -- and just as important, that we are rising to that challenge.

Two weeks ago, I chaired hearings in the U.S. Congress at which scientists from the Arctic ozone expedition presented their findings. Their advice was urgent and clear: to stop the destruction of the stratospheric ozone layer, we must act now, without delay.

The CFC phaseouts endorsed at this conference are an historic step in the right direction. I hope we can go still further. I do not believe that we can afford to wait another decade. I have introduced legislation in the U.S. Congress to require a phaseout within five years. This week, I will introduce new legislation that calls for the recycling and recapture of CFCs and other near-term steps to start reducing emissions right away. For example, I will call for a "CFC deposit," similar to deposits used in some states to encourage recycling of aluminum cans and glass bottles.

I applaud the work of this conference. I hope this will mark the beginning of a new decade of world environmental progress.

WRITTEN ANSWERS TO QUESTIONS SUBMITTED TO DR. ADRIAN TUCK FOR THE RECORD BY THE SENATE COMMERCE COMMITTEE

SENATE SCIENCE, TECHNOLOGY AND SPACE SUBCOMMITTEE HEARING ON ARCTIC AND ANTARCTIC OZONE DEPLETION
FEBRUARY 23, 1989

From Senator Hollings

1. I recognize that you are probably still recovering from the long deployment and rigorous hours of work required during the Arctic expedition. Still, I'd like you to turn your attention to the future.

   What's next? Which key questions about ozone depletion still need to be answered?

Answer

The next key question in my view is to what extent the polar vortices of the lower stratosphere during late winter and early spring export ozone loss to the lower latitude belts which surround them. There are at least three mechanisims by which such loss may occur: (i) formation of the type I PSCs outside the edge of the polar vortex, with some subsequent ozone loss there, (ii) export of chemically perturbed air from inside to outside the vortex, (iii) loss by dilution following the final breakdown of the vortex. Of these, I regard (ii) as potentially the most important.

Are any more research expeditions planned?

Answer

Currently, there are no more expeditions planned, but they are clearly needed beyond 1991.

2. EPA has estimated that ozone depletion will lead to increased UV radiation and millions of additional cases of skin cancer.

   Please outline the other expected impacts of ozone depletion.

Answer

Loss of stratospheric ozone may affect tropospheric climate, but the magnitudes and even signs of the effects are very uncertain. Loss of ozone is likely to cause cooling in the stratosphere.

Increased UV flux at the surface has the potential to cause biological and ecological damage, as well as increased incidence of skin cancer in humans.

Which of the reported impacts worry you the most?

Answer

If (and my impression is that this is a very uncertain area) increased UV fluxes can alter the natural abundances of plankton near the ocean surface, this would be a major cause for concern.

3. Do we understand enough about the proposed CFC replacements to know that they won't harm the ozone layer?

Answer

Calculation of the ozone destroying potential (ODP) of any given CFC or CFC replacement is done by a one or two dimensional photochemical model. A critical quantity is the lifetime of any such molecule in the model stratosphere; such lifetimes are somewhat in question, because of the apparent failure of models to reproduce the low values of tracers such as N_2O, CF_2Cl_2 and $CFCl_3$ observed at 16-20 km in the polar vortices. The likely sign of such an effect would be for the models to overestimate the ODP of a CFC or CFC replacement. In my view, model-based stratospheric lifetimes must be considered uncertain by a factor of two or possibly more.

4. Several of the proposed replacements for CFCs contain hydrofluorocarbons (HFCs) or hydrochlorofluorocarbons (HCFs). HFCs do not deplete the ozone layer, but they are greenhouse gases.

Will they contribute to greenhouse warming as much as CFCs do?

Answer

I don't know the answer to this question.

5. Although we usually try to separate the problems of ozone depletion and global climate change, the two are interrelated. Changes in the chemistry of the stratosphere will lead to changes in temperature as well. Global warming will change ozone depletion rates since the rates of chemical reactions depend on temperature.

Do we know how climate change may affect ozone depletion?

Answer

We know how some individual processes of climate change would affect ozone depletion, but the overall process has sufficient complexity to be beyond our predictive capability at present. It is plausible that CO_2 increase can lead to cooler stratospheric temperatures. In the upper stratosphere, this leads to more ozone production (i.e. less loss from CFCs). In the polar vortices, it could lead to more PSCs in late winter and spring, and hence more ozone loss. However, there is evidence from the recent aircraft missions that major PSC events are faced by synoptic scale weather systems, and it is not known how this mechanism will be affected by climate change. A fair summary would be that we don't know the sign of the effect, let alone the magnitude.

There may be agreement among some scientists that we know how ozone depletion will affect stratospheric temperatures and global climate patterns. In my view, however, we cannot yet predict this with confidence.

From Senator Kasten

6. I understand that with respect to the CFCs, which are the general classification of the substances which cause ozone depletion, that there are some which are much more damaging than others. Also, I understand that there are other substances, which are not CFCs, which have been found to contribute to the problem. As we look toward developing policies on the use of ozone depleting substances, could you comment on whether there are some CFCs which are more damaging than others and whether there are other substances beyond the CFCs on which we should begin to focus?

Answer

This is a complicated subject. From the point of view of ozone depletion, it is qualitatively true that chlorofluorocarbons which contain a double bond or an H atom will do less damage to stratospheric ozone than those which don't, on a molecule for molecule basis. However, many other factors, such as toxicity, safety, affordability and convenience enter into this question. I am not competent to comment on such factors.

Allied Signal

Allied-Signal Inc.
Engineered Materials Sector
P.O. Box 1087R
Morristown, New Jersey 07960
(201) 455-6807

Robert F. Traflet
President Fluorine Products Division

April 25, 1989

The Hon. Albert Gore, Jr.
United States Senator
Washington, DC 20510

Dear Senator Gore:

Enclosed are the responses to the questions submitted to me by you and other Members of the Senate Commerce, Science and Transportation Committee with regard to my testimony before the Committee on February 23, 1989. I was pleased to present Allied-Signal's position on your legislation and would be happy to respond to any further questions you may have.

Yours truly,

Robert F. Traflet

RFT:fso

Enclosure

Q. FROM SENATOR GORE

(1) Why hasn't Allied released all thermophysical data on substitutes it has investigated to user groups so they can evaluate the merits of various refigerants and mixtures on their own?

Response:

Amongst the companies engaged in chlorofluorocarbon substitute research, ALLIED-SIGNAL has been at the forefront in developing and quickly disseminating information on physical and thermodynamic properties of the entire range of substitutes to user groups directly involved in the redesign and conversion of CFC-containing systems and equipment. We have a dedicated group of scientists whose prime function is to estimate and then to determine, with great precision and accuracy, the thermophysical properties of chlorofluorocarbon substitutes. Our business has committed substantial cost, resources and effort to generate this information, and the end products have been internationally recognized as some of the highest quality thermophysical data on this class of chemicals. This information has been and will continue to be promptly shared with the widest range of end-users in the refrigeration and air-conditioning industries. Indeed, it is in ALLIED SIGNAL's best interest to work closely with end-users so that we can help to facilitate the timely switch from ozone depleting chlorofluorocarbons to environmentally acceptable substitutes. ALLIED SIGNAL scientists gave the first public, technical papers on the physical and thermodynamic properties of HFC-134a and will provide similar information on HCFC-124 at a forthcoming meeting of the AMERICAN SOCIETY OF HEATING, REFRIGERATION AND AIR CONDITIONING ENGINEERS. ALLIED SIGNAL expects to continue its policy of providing timely and accurate thermophysical data on the entire range of substitutes to enable end-users to evaluate and apply these products well in advance of their commercial availability.

Q. FROM SENATOR HOLLINGS

(2a) Any comprehensive strategy to cut CFC emissions will require developing CFC alternatives, developing new technology, and instituting CFC recycling programs.

Which steps do you think will yield the largest reduction in emissions most quickly and for the least effort?

Response:

We believe that there are a number specific CFC recycling programs which could be instituted or encouraged to significantly reduce CFC emissions in the near term. For example, CFC-113 reclaim and recycling centers are already in place at various locations throughout the U.S. Presently, modest amounts of "spent" or used CFC-113 are returned by end-users to these centers for reconstitution. If this practice is encouraged and low emission equipment and modifications such as carbon absorbtion are utilized, a greater proportion of the 150M lb. of CFC-113 used annually could be conserved.

At the present time, the recycle of CFC-12 from automotive air conditioning systems is being actively supported by the automotive industry. Quality specifications for recycle CFC-12 will soon be set and multiple locations equipped to recover used CFC-12 from autos. It has been estimated that once such a system is in full operation, some 30 million pounds of CFC-12 could be recovered for recycle.

Possibly the largest intermediate term reduction in CFC emissions could take place in the rigid urethane industry as end-users switch from CFC-11 as a blowing agent to a

substitute such as HCFC-141b. Urethane producers have an ongoing, active program to evaluate and qualify substitutes and they would be in a position to utilize such a product without major modifications of their operations. Similarly, HCFC 141b azeotropes may provide opportunities to substitute for CFC 113 in precision cleaning and defluxing after equipment modifications. If HCFC-141b proves acceptable toxicologically and continues to show acceptable performance, a major reduction in the CFC-11 and CFC113 agent use is possible in the 1992-1993 time frame as HCFC-141b become available commercially.

Q. FROM SENATOR HOLLINGS

(2b) Are their federal laws and regulations that are making cutting CFC emissions more difficult?

Response:

There are two areas where federal regulations have slowed certain facets of CFC emission reduction.

There is a significant use of CFC-113 based solvents, perhaps as much as 25%, by military contractors which must conform to various military specifications requiring the use of these materials. Changes to these types of military specifications have traditionally been very slow. To encourage the use of non-CFC solvents and other cleaning methods in these areas, mechanisms to more quickly qualify under the military specifications are desirable. This is a recognized barrier and the EPA has formed an ad hoc committee to rectify the situation. We are serving on that committee.

The second area where federal regulations have been a barrier is in the delays experienced in permitting of waste solvent collection depots. These are staging areas where waste CFC solvents are collected prior to being shipped to recycling centers. The lack of these sites complicates the logistics of solvent recycling especially for the small CFC solvent users. We think that a speed up of such permitting poses no environmental risk.

Q. FROM SENATOR HOLLINGS

(3a) The federal government spends millions of dollars a year funding R&D on replacing CFCs. One program at the National Institute of Standards and Technology which evaluates CFC alternatives was recently expanded.

Have such programs been useful?

Response:

The usefulness of government funded R&D varies tremendously. In virtually every case, the utility could be improved via better communication with end-users and suppliers such as ALLIED-SIGNAL. The NIST program to generate precise thermodynamic and transport data on R-123 is of great value, although we feel that the proposed form of the thermodynamic equation is cumbersome and could have been improved by increased dialogue with industry. We continue to maintain an open door policy with NIST and other government R&D agencies to provide expert advice and consulting to help direct their technical efforts, as recently exemplified by our hosting the EPA AIR AND ENERGY ENGINEERING RESEARCH LAB of Research Triangle Park, N.C. at ALLIED-SIGNAL's BUFFALO RESEARCH LABORATORY on February 21, 1989.

(3b) In your opinion, which of these programs should the Congress consider expanding?

The programs which are appropriate for increased government funding would include thermophysical property measurements for more alternates and generic material compatibility evaluations of common materials of construction and realistic replacements.

Q. FROM SENATOR HOLLINGS

(4) Dr. Watson mentioned that the concentration of carbon tetrachloride in the atmosphere is increasing more than 1% per year. While carbon tetrachloride is not a CFC it does cause ozone depletion, yet scientists have not been able to identify the sources responsible for this increase.

If you had to guess, who would you blame for the increasing amount of carbon tetrachloride in our atmosphere?

How much carbon tetrachloride is produced in the United States each year?

Response:

ALLIED-SIGNAL does not manufacture carbon tetrachloride. I'm certain that others more familiar with the manufacturing and uses of carbon tetrachloride are much more capable of answering this question than I am.

Q. FROM SENATOR HOLLINGS

(5a) The production processes for CFC alternatives are much more complicated than the simple processes used to make most CFCs.

How much more expensive will CFC alternatives be?

Response:

It is impossible for us to estimate the cost of the substitutes at this time. We have process technology research that is ongoing and pilot plant assessments yet to be made. Without question, however, the cost of the substitutes will be greater than the current cost of the controlled product.

(5b) Will production of CFC alternatives lead to dangerous by-products which will be difficult to dispose of?

Response:

The production processes for several of the CFC substitutes under study may lead to very small amounts of one or two by-products with potential toxicity greater than many chemical products used commercially. There are numerous chemical and physical methods to destroy such by-products, and the most effective method will be incorporated into the production process so that both production and consumption of substitutes will be entirely safe. In addition, small amounts of CFCs may be formed as by-products in the synthesis of some substitutes. Here again, both physical and chemical methods are available to destroy the minute quantities of substitutes which would not add to emission of any CFCs to the atmosphere. We are presently studying and evaluating several alternative production processes with the direct objective of minimizing or eliminating all by-product formation and in so doing, develop the safest most cost effective process possible. It is very likely that we will be able to hold the formation of the by-products to a minute percentage of the product, but less likely that they can be entirely eliminated since the high temperature chemical reactions required to form substitutes, such as HFC-134a, are almost always accompanied by undesired parallel reactions leading to by-products. These by-products will be disposed in the most responsible manner possible.

Q. FROM SENATOR HOLLINGS

While carbon dioxide is the largest contributor to greenhouse warming, CFCs are responsible for about a fifth of the problem. Many of the replacements for CFCs are also greenhouse gases.

(6a) Are they better or worse than CFCs in this respect?

Response:

The atmospheric Lifetime of CFCs range from about 70 years to 600 years, whereas the replacement candidate's lifetimes vary from approximately 2 to 35 years. By virtue of their much shorter atmospheric lifetimes, the replacements will contribute substantially less to "greenhouse warming" at equivalent release rates to the atmosphere. Therefore, they are better than CFCs in this respect. In fact, the substitute for CFC-12 has only about one-tenth of its greenhouse potential.

(6b) Would you be hesitant to go into production of a CFC replacement that was a worse greenhouse gas than the CFCs they replace?

Response:

Uncertainty in the business world is part of being in business, in fact we expect it. Presently, ALLIED-SIGNAL is looking at an investment of $250 million to commercialize substitutes for the CFCs controlled by the Montreal Protocol. The bulk of this expenditure will occur when we commit to building new plants or re-engineering our existing plant system to produce the substitutes.

Our management has been very supportive of our commercializing efforts and, without prejudging their decisions, I am confident of their continued support.

Lately, however, I have become more cautious in my predictions. Your question about the greenhouse concerns of substitutes is a case in point. First, we don't fully understand the indirect greenhouse implications of the substitutes. Secondly, however, your question goes to the heart of what I consider to be the key issue facing the

substitutes. Are they going to be regulated and if so, how and when?

It's my responsibility to make certain that management is fully informed about all the implication of a major decision such as the one we face with commercializing the substitutes. I would be less than candid if I told you that I feel as strongly about the direction of commercialization as I did six months or a year ago. All of the discussion about regulating the substitutes and using CFCs as a revenue measure is making us look long and hard at the next big step which for us at ALLIED-SIGNAL is very close.

Q. FROM SENATOR PRESSLER

(7) Are CFC substitutes safe? Some substitutes are only 5% as destructive as the current chemicals. Is 5% too high? Can you do better, and if so, at what cost?

Response:

ALLIED-SIGNAL will not commercialize products that are not safe. As I stated in my testimony we have several testing projects underway within ALLIED-SIGNAL and we are members of a an international group of CFC producers conducting substitute testing.

In regard to the question of the safety of the substitutes, one brief comment. We are working to develop and commercialize substitutes for those products controlled by the Montreal Protocol. One of those not controlled by the Protocol is CFC 22 which has always been considered part of the solution to ozone depletion. Presently, resources are not available to search for substitutes for CFC-22 while we work on substitutes for the others. This is not a question of money, it's a question of what is possible in the short term. We would also be concerned that any proposed controls on CFC 22 would dampen efforts to rapidly switch over to it from CFC 11 and 12.

Q. FROM SENATOR PRESSLER

(8) How much of an investment must the CFC industry make in substitutes? Might developing countries enter the market for the old CFCs if we abandon them unilaterally?

Response:

I can only comment on the investment that we at ALLIED-SIGNAL envision will be required to commercialize the substitutes. As I said in my testimony, $250 million will be required for all the work necessary to begin bringing these products to the marketplace in the next decade. This figure includes research, pilot plants, toxicological testing, engineering and plant construction among other items.

Whether or not lesser developed countries begin to manufacture controlled CFCs is something that I can only answer as far as ALLIED-SIGNAL is concerned. We have a corporate policy that we will not license CFC technology to lesser developed countries. However, I'm concerned about this issue and believe that UNEP should monitor it carefully.

Q. FROM SENATOR PRESSLER

(9) Will users of CFCs be able to "drop substitutes into" production of goods?

Response:

Every producer is hoping to find drop-in substitutes for the products regulated by the Montreal Protocol. Just within the last few weeks we have developed a drop-in substitute for a blend of CFC-12 and ethylene oxide. This blend is used as a sterilant gas by hospitals and the health care industry to sterilize reusable surgical equipment and health care goods. The current market for the blend is 30 million lbs.

Our research is continuing into substitutes for all applications of the controlled products and although it looks less and less likely that drop in substitutes will be found for broad application, our research attempts are moving forward.

Q. FROM SENATOR PRESSLER

(10) Should we accelerate the schedule set forth in the Montreal Protocol? Should we take unilateral action?

Response:

Our policy is that we support the Montreal Protocol and believe it should be amended to further restrict the manufacture and use of CFCs. Last year's Ozone Trends Panel Report and the scientific assessment called for by the Protocol to be completed this summer should be the basis for this revision. We believe that only through continued international efforts can the problem of ozone depletion be dealt with effectively.

Q. FROM SENATOR PRESSLER

(11) What incentives should the federal government provide to make CFC substitutes affordable and useful?

Response:

At the present time, I believe the market is going to make the substitute products affordable and usable. One of the success stories of this search for substitutes is the fact that the implementation of Montreal Protocol has levelled the playing field around the world rather than just in one county. This will allow a real market place approach to work.

Q. FROM SENATOR KERRY

(12a) Incomplete basic data for design of world scale plants capable of high yields at favorable investment and operating costs.

Response:

ALLIED-SIGNAL is working at a vastly accelerated pace to simultaneously perfect processes for a full family of CFC substitutes, and at the same time, gain basic design data in part through the operation of pilot plants so that world scale plants can be built and operated safely as soon as possible. Last June, we announced a pilot plant for HCFC-141b. This will soon be followed by additional CFC substitute plant now under construction. We continue our laboratory process development in parallel with pilot plant construction and operation so that full plant design data can be obtained as early as possible. This vastly accelerated and high risk process development effort will lead to the construction of an HCFC-141b plant early in 1992. Additional substitute commercial facilities will follow in the 1993-1994 time period.

(12b) Lack of complete toxicity profiles for all of the alternative candidates.

Response:

ALLIED-SIGNAL is a member of the industrial groups which are sponsoring toxicity tests on many of the CFC substitutes and we are desirous of extending the toxicity testing to include additional potential CFC substitutes. It is our understanding that from the inception of testing, a complete toxicity evaluation requires five to six years. Since such toxicity testing has already commenced on HCFC-123, 141b, and HFC-134a, it is entirely conceivable that we may begin to learn of final toxicity results on one or more of these compounds by late

1992. ALLIED has consistently maintained a policy of non-interference with either the timing or direction of the toxicity tests. In this way, we feel that independent, reliable and reproducible results will be generated, and if the substitutes are proven non-toxic, the public at large may have sufficient confidence to use them.

(12c) Incomplete or inconsistent thermodynamic and transport property information on all of the identified alternatives.

Response:

As noted, in the response to question NO. 1, ALLIED develops and disseminates appropriate thermodynamic/thermophysical data on candidates early in the developmental/commercialization process. This is an expensive, time-consuming task which involves the commitment of significant resources. Such efforts must be justified by a reasonable anticipation of achieving product commercialization.

Those molecules which have little likelihood of commercialization, due to inherent safety risks, infeasibility of manufacturing process, or improbable commercial demand, are less likely to receive an equivalent level of effort to precisely characterize their properties. In such cases, estimation methods have been developed adequate to support early assessment. Some of these methods are in the public domain. Others may not be.

NIST has stated that they hope to develop a generic model suitable for characterizing molecules for which limited measured data is available. ALLIED supports this concept. It should still be understood, though, that more careful and precise characterization is still likely to be required on those molecules which eventually emerge as viable working fluids.

(12d) Incomplete development of equipment that can use the alternatives.

Response:

Refrigeration systems and individual system components are designed and optimized for specific refrigerants to achieve reliability and operating efficiency. Direct "drop-in" refrigerants are thus infeasible to varying degrees depending on the extent of divergence of the new candidate fluid to reference fluid.

Whenever the design refrigerant is changed, the system must be re-optimized and may require substantive design changes to achieve acceptable performance and reliability. The known substitute candidates for CFC-11 and CFC-12 replacement will require significant equipment and system changes to achieve these objectives. These efforts are actively being pursued by systems and component manufactures with appropriate technical support by ALLIED-SIGNAL.

The extent of the effort and the timeliness can vary significantly by application and by the types of adjustments and redesign imposed by the replacement fluid.

In virtually every area of refrigerant application, this task is underway but incomplete. The phasedown schedule in the current Montreal Protocol already severely taxes the ability of the various end-users to accomplish and incorporate the essential product redesign. Accelerated phasedown will certainly exacerbate an already difficult challenge.

(12e) Signals at EPA and in the halls of Congress that some of the identified alternatives will have insufficient product lifetimes to justify the investment needed for us to produce them and for our customers to develop equipment to use them.

Response:

I believe that this question was answered in 6(B), but briefly we are concerned about what we have recently heard from Congress and the Administration that raises some question about how fast we should continue moving forward. Uncertainty, can never be removed from decision making, however, we certainly can minimize the impact of that uncertainty by waiting to commit the bulk of the $250 million we expect to spend until we understand the shape of the market for which we are developing products.

(12f) High capital needs and an uncertain business climate.

Response:

We feel very strongly that CFCs are not appropriately used as a revenue raiser. We need to generate capital in order to do the research and retooling to ultimately make a new business. Plants in our system which were scheduled to last another 20 to 30 years are becoming obsolete virtually overnight and need to be replaced.

(12g) Threats in the U.S. of auctions or taxes that will divert needed revenue streams from the private sector to the government's general fund.

Response:

In regard to the auction permit system that has been discussed, we feel that it is also unnecessarily disruptive. It is essential that a market exist for these new products when they become available in the early 1990's. The auction system would only be in place for a very short period of time but may destroy the market for the future. The strongest

voices in the economy would be rewarded which may eliminate some beneficial uses of CFCs and their substitutes. I also believe that several questions about the legality of the system also need to be addressed and understood before it should ever be considered.

We also believe that industry in general will find such product specific revenue raising objectionable and a threat to the ability to plan for future capital investment and to be competitive in world markets.

(12h) The need to complete development, evaluation and design of retrofit technologies so the current equipment which relies on CFCs (U.S. investment signs exceeds $135 billion) will serve for its useful life.

Response:

ALLIED-SIGNAL supports the objective of implementing retrofit technologies where feasible to accomplish the objectives of an expedited phasedown of CFCs. We caution, however, that this should not be allowed to interfere with or delay the accomplishment of the primary goal which is to develop and implement permanent, long term environmentally acceptable solutions for future systems.

The current status of retrofit technologies varies dramatically depending on particular hardware and refrigerant properties. Most of this effort must be carried out by the equipment manufacturers with the help of knowledgeable refrigerant producers such as ALLIED-SIGNAL. Even within specific industries, one manufacturer's equipment may be more capable of being retrofit than anothers.

It is our observation that most manufacturers are already addressing this issue. ALLIED-SIGNAL is supporting such efforts wherever possible. It appears that such efforts will be most fruitful once the technology of applying the alternatives to new systems is better advanced. We strongly recommend that the implementation of retrofit technology be regarded as an important, but secondary, objective and that it not be mandated to the detriment of the overall industry effort.

The Federal Government can do much to provide an atmosphere conducive to effecting these changes. Specific examples would include the following:

- EPA could eliminate or reduce the barriers to recycling of existing refrigerants. Pre-emption of unnecessarily restrictive state and local requirements could promote this activity.

- DOE could delay the imposition of new energy efficiency requirements until the final impact of replacements can be evaluated. This would also reduce the dilution of resources of equipment manufacturers so that they can focus initially on replacements and then on retrofit.

- NIST could perform a very useful function by conducting "generic" research on alternate fluids. Some suggestions might be:

    a. developing certified standard thermophysical properties on leading alternatives, resolving discrepancies between various disseminated "engineering quality" data.

b. developing highly accurate mathematical models to represent the thermophysical property data of fluorocarbon mixtures where only pure fluid data is available.

c. developing cycle simulation and experimental confirmation capabilities to evaluate the energy efficiency of alternates.

Q. FROM SENATOR KERRY

(13) DOE currently is in the process of promulgating new regulations for improving the energy efficiency of home applicances. At the same time, refrigerator manufacturers are concerned that they will soon be required to replace CFCs refrigerants. I understand that these substitutes are not as energy efficient. This situation obviously has the potential to have a serious negative impact on the industry.

Can you offer any suggestions for improving the regulatory process to reduce such conflicts?

How can the industry become more constructively involved in the regulatory process?

Response:

As I said in my testimony to this committee and to others, CFCs have many societal uses for which no substitutes exist. This is an example of laudable government initiatives in conflict, one for energy efficiency and the other for environmental protection.

We are working very closely with appliance manufactures but unfortunately there are no easy solutions. CFCs provide the cool temperatures that allow a refrigerator to do its job, but they are also vital components of the foam wall that provide insulation to let it work efficiently.

I don't have an easy answer to this dilemma. I would recommend that the DOE and EPA coordinate their programs in order to minimize the disruption to the appliance industry that may be caused as a result of these initiatives being at crosspurposes. It may be that the timetables under consideration by the DOE need to be adjusted to reflect substitute research.

Q. FROM SENATOR KERRY

(14) It is my understanding that CFC 113 is currently used to clean computer chips. What types of alternatives are being developed in this area? How quickly can new methods be developed and implemented? What impact will this have on the computer industry?

Response:

ALLIED-SIGNAL has developed and announced to the electronics industry in March a new family of low ozone depleting solvents based on HCFC 141b. These new solvents, which would have approximately 1/10 the ozone depletion potential of CFC 113,

could be used in most of the CFC 113 cleaning applications of the electronic/computer industry. Our preliminary tests indicate that it performs as well as or better than the current CFC 113 based solvents.

ALLIED-SIGNAL's timetable calls for the commercial availability of these solvents in mid 1992. This timing is dependent on the successful completion of adequate toxilogical testing and commercial plant construction.

Because the electronics industry is familiar with the performance and reliability of CFC cleaning processes, the change over to a HCFC solvent would generally be viewed by the electronics industry, we believe, as a lower risk and less disruptive than going to other alternative cleaning technologies.

Q. FROM SENATOR KASTEN

(15) Shouldn't we stress the need for an international effort if we're going to control the technology of production of CFCs and their use in end products? Don't we have to guard against adopting a U.S. CFC ban, which could just result in having foreign countries continue to use ozone depleting products and the U.S. importing the end products? This would not only continue the environmental harm, but cause unilateral economic harm to the U.S. Could you comment on this please?

Response:

Allied Signal is firmly committed to a global solution to the problem of ozone depletion. Unilateral sanctions on this subject tend to be counterproductive and be of limited environmental benefit. You have raised several key points in your question that argue against unilateral action.

Our policy is that further reductions in the production and uses of CFCs should occur, but only through the process established by the Montreal protocol. To do otherwise raises a host of trade and competitiveness issues that don't arise if we continue to operate on an international basis.

Q. FROM SENATOR McCain

(16) How does the cost of possible substitute compounds compare with those currently used?

Response:

It is impossible for us to estimate the cost of the substitutes at this time. We have process technology research that is ongoing and pilot plant assessments yet to be made. Without question, however, the cost of the substitutes will be greater than the current cost of the controlled product.

Q. FROM SENATOR McCain

(17) Concerns have been raised that implementation of the Montreal Protocol will result in windfall profits for producers and that the financial gain might discourage companies from marketing substitutes as soon as possible. What are your views on this?

Response:

This issue has been raised a number of times by various people and we have always disagreed with it because it doesn't take into account that businesses operate for the long term, not the short term. We have tried to demonstrate that a race between very large research driven international companies is well underway as a result of the Montreal Protocol. The reason is fairly simple--there is a market that needs to be served waiting for these substitutes.

It's very important that the Committee understand that the market is going to be in a disrupted condition for a relatively short period of time, probably 7-10 years before it is largely changed over to substitutes. We need to maintain a market or else there will be no one to utilize the substitutes. Would it be a smart business decision to so maximize our profits in the short term that we destroy the market for these new products that we are trying so hard to develop and commercialize? I don't think it would be. Just like ever other company involved in the search for substitutes, we want to be the first one with a product in the market. We have no intention of holding back anything from the marketplace that will make a contribution to helping solve the problem of ozone depletion.

0131C

9. Will users of CFCs be able to "drop substitutes into" production of goods?

10. Should we accelerate the schedule set forth in the Montreal Protocol? Should we take unilateral action?

11. What incentives should the federal government provide to make CFC substitutes affordable and useful?

From Senator Kerry

12. The following barriers to replacing CFCs were listed by Dr. Glas in his prepared testimony:

    -- Incomplete basic data for design of world scale plants capable of high yields at favorable investment and operating costs.

    -- Lack of complete toxicity profiles for all of the alternative candidates.

    -- Incomplete or inconsistent thermodynamic and transport property information on all of the identified alternatives.

    -- Incomplete development of equipment that can use the alternatives.

    -- Signals at EPA and in the halls of Congress that some of the identified alternatives will have insufficient product lifetimes to justify the investment needed for us to produce them and for our customers to develop equipment to use them.

    -- High capital needs and an uncertain business climate.

    -- Threats in the U.S. of auctions or taxes that will divert needed revenue streams from the private sector to the government's general fund.

    -- The need to complete development, evaluation and design of retrofit technologies so the current equipment which relies on CFCs (U.S. investment alone exceeds $135 billion) will serve for its useful life.

What is the status and our time table for overcoming each of these barriers, and how can the government, EPA, DOE, and NIST help in speeding up the process and overcoming these barriers?

NEWS FROM

U.S. Senator Al Gore

(D - Tennessee) SR 393 Russell Building, Washington, D.C. 20510 (202) 224-4944

FOR IMMEDIATE RELEASE
WEDNESDAY, February 22, 1989

CONTACT: Marla Romash
202-224-4944
202-547-0806 (H)

MEDIA ADVISORY
HEARING ON OZONE DEPLETION SET FOR TOMORROW, FEBRUARY 23
First Congressional Hearing on Arctic Study

WASHINGTON -- The first Congressional hearing on the findings of an international team of scientists just returned from studying ozone depletion above the Arctic will be held tomorrow, Thursday, Feb. 23, beginning at **9:30 A.M. in Room 253 of the Russell Senate Office Building.**

The Senate Commerce Committee's Subcommittee on Science, Technology, and Space, chaired by U.S. Sen. Al Gore, D-TN, will hear from scientists on the team from the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration.

Also testifying will be representatives from private industries involved in developing alternatives to chloroflourocarbons, the chemicals principally responsible for the destruction of the earth's protective ozone shield in the upper atmosphere.

Scientists have found a hole in the stratospheric ozone above Antarctica and the potential for similar damage to the upper ozone above the Arctic. The scientists' findings, the implications of those findings, and alternative technologies to replace CFCs, commonly used, among other things, in air conditioning and refrigeration, will be discussed.

##

FOR IMMEDIATE RELEASE
WEDNESDAY, February 22, 1989

CONTACT: Marla Romash
202-224-4944
202-547-0806 (H)

MEDIA ADVISORY
HEARINGS ON OZONE DEPLETION SET FOR TOMORROW, FEBRUARY 23
First Congressional Hearing on Arctic Study

WASHINGTON -- The first Congressional hearing on the findings of an international team of scientists just returned from studying ozone depletion above the Arctic will be held tomorrow, Thursday, Feb. 23, beginning at **9:30 A.M. in Room 253 of the Russell Senate Office Building.**

The Senate Commerce Committee's Subcommittee on Science, Technology, and Space, chaired by U.S. Sen. Al Gore, D-TN, will hear from scientists on the team from the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration.

Also testifying will be representatives from private industries involved in developing alternatives to chloroflourocarbons, the chemicals principally responsible for the destruction of the earth's protective ozone shield in the upper atmosphere.

Scientists have found a hole in the stratospheric ozone above Antarctica and the potential for similar damage to the upper ozone above the Arctic. The scientists' findings, the implications of those findings, and alternative technologies to replace CFCs, commonly used, among other things, in air conditioning and refrigeration, will be discussed.

##

MEMORANDUM

FOR: SENATOR GORE

FROM: MIKE NELSON

RE: ATTACHED MEMO AND ARTICLES

February 26, 1989

Attached are:

1. A memo outlining a possible hearing on the possibility that global warming will lead to sudden, possibly catastrophic, environmental change. If it looks good to you, I would like to sit down with you for 20-30 minutes and discuss which themes you would want to emphasize at the hearing and what you would want out of it.

2. Editorial from the latest issue of Science on the importance of the Arctic in global change. The key points of the editorial are:

    1. Present models of how the Arctic affects climate change are simplistic and may be wrong.

    2. The geological record of the Arctic holds the key to improving these models.

    3. There are several interesting feedback mechanisms that may be at work in the Arctic, including those due to changes in albedo and cloud cover.

3. News article from the latest issue of Science showing that the global average temperature for 1988 was slightly warmer than that for 1989, although the difference is not statistically significant. So Jim Hansen was right last summer, but just barely.

4. Rough outline of a hearing on methane and its role in global change. I'll get more details to you later.

MEMORANDUM

FOR: SENATOR GORE
FROM: MIKE NELSON THRU RICK ADCOCK
RE: GLOBAL CHANGE HEARING ON "SURPRISES IN THE GREENHOUSE"

February 26, 1989

GLOBAL CHANGE HEARING PROPOSAL.

When Marty, Pat, and I discussed the Science Subcommittee's goals with you in January, you mentioned several global change hearings you would like to hold. Since we have had a hearing on ozone depletion, we would suggest that the next one be on whether global warming will lead to sudden, unpredictable, even catastrophic, change.

As you know, most computer models of global warming predict slow, gradual changes in temperature and precipitation. Yet, most scientists will tell you that they expect environmental change to occur in fits and starts, in unexpected ways. This is one of the main lessons of the geological record. After the last Ice Age, major warming events occurred in just a couple decades. The Gulf Stream completely changed course in less than a century. Last year's drought provided another example of an unpleasant surprise. It was easy to predict that crop yields would fall because of the drought, but no one expected the Mississippi River to fall so low that barge traffic and power plant cooling systems would be affected. It's almost certain that greenhouse warming will cause similar unpleasant surprises.

With global warming, the scientific consensus is that the millions of tons of carbon dioxide, CFCs, and other greenhouse gases that we have dumped into the atmosphere will cause some warming. That conclusion is about as close to certain as you can get in science. The uncertainty comes in when we try to answer questions like: How much? How quickly? Where will it be worst? This proposed hearing would allow you to explore these uncertainties, hear more about some of the unpleasant surprises we might face in the future, and examine the policy implications of those surprises.

ARCHITECTURE OF HEARING

Focus. A hearing focused on these surprises would provide an opportunity to make it clear that global warming won't be something we can slowly adjust to. It will also provide a chance to highlight some very interesting work on past climate changes, instead of focusing on only computer models of the future climate.

Scientific questions. The hearing would raise and provide preliminary answers to these questions: Is rapid, unpredictable change an inherent part of the climate system? The rapid environmental changes seen in the geological record occurred naturally, without man's interference in the Earth system. How much more rapid and unpredictable will future changes be now that

man has perturbed the system? What can be done to improve research on past global change? Most global change researchers agree that research on paleo-environments has been underemphasized. What additional work needs to be done on sudden global change?

Policy implications. The hearing will build a record to support two points. First, because surprise changes are quite possible, we need additional research and improved computer models that take these surprises into account. We must take steps now to help us predict sudden as well as gradual changes. Second, policymakers must begin now to consider these sudden changes and should adjust their scenarios and plans accordingly.

Visuals. Besides having the standard pictures of general circulation models, one of the researchers who studies paleo-environments could show slides of what the climate models mean on the ground. In addition, he could show what the U.S. looked like during the last Ice Age when the average global temperature was about 5 degrees Celsius colder than today. For instance, he could show pictures of Minneapolis now and 18,000 years ago (when it was under a mile of ice and looked like Antarctica). Just comparing the radical ecological changes that have taken place in the Washington, D.C. area would make a big impact. By illustrating these huge differences, he could emphasis the kind of dramatic change that we might expect with a 5-degree warming.

Press. For the members, the press, and the public, this would be a new kind of hearing. There have been dozens of hearings where atmospheric modelers discuss their predictions of future climates, but so far there has not been a good discussion of the huge, sometimes catastrophic, changes which have occurred in the past and might occur in the future.

POTENTIAL TOPICS AND WITNESSES

<u>First Panel</u>

Overview of sudden global change. A climate modeler like Warren Washington (NCAR), Gerry Mahlman (NOAA's Fluid Dynamics Lab), or Jim Hansen (NASA Goddard) could discuss why present models cannot adequately model many of the processes that might lead to sudden global change. They could discuss what the models tell us--that global warming will occur--and delve into the unmodelled phenomenon that might lead to unexpected change.

Policy implications. Dr. William Clark is a natural scientist at Harvard who studies the societal implications of global change. He has written extensively about how the uncertainties of global change make it all the more imperative that we do something about the problem. He was the last witness on the second panel at the February 22 full committee hearing on global change. Unfortunately, he didn't discuss the problem of uncertainty much and there wasn't much time to quiz him at the last hearing. He's excellent in Q&A and is definitely worth having back.

Second panel on examples of sudden global change

Carbon dioxide surge. Since 1987, carbon dioxide levels have been increasing at an unprecedented rate. This temporary surge is apparently due to decreased plant growth resulting from El Nino and last year's droughts. This surge highlights the critical role of the biosphere in controlling carbon dioxide levels. Rick Adcock suggested that we get Dr. Keeling (of Mauna Loa curve fame) from UC San Diego to cover this.

West Antarctic ice sheet. A large research effort is focused on examining the possibility that the West Antarctic ice sheet is unstable and likely to catastrophically melt in response to global warming. There is some evidence that this has happened in the past, causing sea level to rise more than 2 meters in a few decades. Such a rapid sea level rise is much more rapid than that predicted to occur due to thermal expansion of the oceans. Possible witness: Dr. Charles Bentley (Wisconsin).

Methane from melting permafrost. The possibility that methane released from melting permafrost may lead to increased global warming and even more permafrost melting, resulting in a runaway warming effect, would be worth examining. Dr. Art Lachenbruch, a noted geophysicist at the U.S. Geological Survey, has documented some warming of Alaskan permafrost and would be a good witness.

Rapid climate changes recorded in ice cores. As you know from your visit to Antarctica, the ice cores record several rapid changes in temperature and atmospheric composition over the last 100,000 years. It would be useful to discuss the implications of those changes.

Chaos in climate models. The new science of chaos has already found several applications in climate modelling. Ed Lorenz, an MIT meteorologist, was one of the first researchers to discover the potential for chaotic behavior in weather prediction models. He found that very small changes in initial temperatures put into his models could cause large changes in model predictions. Many researchers suspect that improving climate models will require taking into account such chaotic behavior.

Environmental reconstructions. The Cooperative Holocene Mapping Project (COHMAP) consists of a team of geologists, biologists, climate modelers, and others who have reconstructed the global climate for the last 18,000 years. They can provide the details about how much regional climates changed in response to global warming after the Ice Age. Just 18,000 years ago, the forests of Tennessee were like those in northern Maine today. The deserts of the American Southwest had more lakes than Minnesota. The COHMAP members could also discuss problems that general circulation models have in matching past climates.

POSSIBLE DATES. The second or third week in April, would be the best timeframe for this hearing.

SCIENCE

17 FEBRUARY 1989
VOLUME 243
NUMBER 4893

American Association for the Advancement of Science
Science serves its readers as a forum for the presentation and discussion of important issues related to the advancement of science, including the presentation of minority or conflicting points of view, rather than by publishing only material on which a consensus has been reached. Accordingly, all articles published in *Science*—including editorials, news and comment, and book reviews—are signed and reflect the individual views of the authors and not official points of view adopted by the AAAS or the institutions with which the authors are affiliated.

Publisher: Philip H. Abelson, *Acting*

Editor: Daniel E. Koshland, Jr.

Deputy Editor: John I. Brauman (*Physical Sciences*)

EDITORIAL STAFF
Managing Editor: Patricia A. Morgan
Assistant Managing Editor: Nancy J. Hartnagel
Senior Editor: Eleanore Butz
Associate Editors: Keith W. Brocklehurst, Martha Coleman, R. Brooks Hanson, Barbara Jasny, Katrina L. Kelner, Edith Meyers, Linda J. Miller, Phillip D. Szuromi, David F. Voss
Letters Editor: Christine Gilbert
Book Reviews: Katherine Livingston, *editor*
This Week in *Science*: Ruth Levy Guyer
Contributing Editor: Lawrence I. Grossman
Chief Production Editor: Ellen E. Murphy
Editing Department: Lois Schmitt, *head;* Mary McDaniel, Patricia L. Moe, Barbara E. Patterson
Copy Desk: Joi S. Granger, Jane Hurd, MaryBeth Shartle, Beverly Shields
Production Manager: Karen Schools Colson
Assistant Production Manager: James Landry
Graphics and Production: Holly Bishop, James J. Olivarri, Yolanda M. Rook
Covers Editor: Grayce Finger
Manuscript Systems Analyst: William Carter

NEWS STAFF
News Editor: Barbara J. Culliton
Deputy News Editors: Roger Lewin, Colin Norman
and Comment/Research News: William Booth, Gregory Byrne, Mark H. Crawford, Constance Holden, Richard A. Kerr, Eliot Marshall, Jean L. Marx, Robert Pool, Leslie Roberts, Marjorie Sun, M. Mitchell Waldrop
European Correspondent: David Dickson
Contributing Writer: John Walsh

BUSINESS STAFF
Circulation Director: John G. Colson
Fulfillment Manager: Ann Ragland
Business Staff Manager: Deborah Rivera-Wienhold
Classified Advertising Supervisor: Karen Morgenstern
Guide to Biotechnology Products and Instruments: Shauna S. Roberts

ADVERTISING REPRESENTATIVES
Director: Earl J. Scherago
Traffic Manager: Donna Rivera
Traffic Manager (Recruitment): Gwen Canter
Advertising Sales Manager: Richard L. Charles
Marketing Manager: Herbert L. Burklund
Employment Sales Manager: Edward C. Keller
Sales: New York, NY 10036; J. Kevin Henebry, 1515 Broadway (212-730-1050); Scotch Plains, NJ 07076: C. Richard Callis, 12 Unami Lane (201-889-4873). Chicago, IL 60914: Jack Ryan, 525 W. Higgins Rd. (312-885-8675). San Jose, CA 95112: Bob Brindley, 310 S. 16th St. (408-998-4690); Dorset, VT 05251: Fred W. Dieffenbach, Kent Hill Rd. (802-867-5581); Damascus, MD 20872: Rick Sommer, 11318 Kings Valley Dr. (301-972-9270); U.K., Europe: Nick Jones, +44(0647)52918; Telex 42513; FAX (0647) 52053

Information for contributors appears on page XI of the 23 December 1988 issue. Editorial correspondence, including requests for permission to reprint and reprint orders, should be sent to 1333 H Street, NW, Washington, DC 20005. Telephone: 202-326-6500.

Advertising correspondence should be sent to Tenth Floor, 1515 Broadway, New York, NY 10036. Telephone 212-730-1050 or WU Telex 968082 SCHERAGO, or FAX 212-382-3725.

The Arctic: A Key to World Climate

The Arctic is part of a great global heat engine. Changes in the arctic atmosphere, ocean, sea ice, and permafrost are early precursors to climate change elsewhere. In the past, those changes have been drastic. Only 18,000 years ago, virtually all of Canada and some of the United States were covered by a thick layer of ice.

At the recent AAAS Annual Meeting, a symposium brought together some of the leading research scientists active in studies of resources and climate.* In one of the sessions, speakers reviewed information about the evolution of the arctic climate.

A principal impression that could be drawn from the symposium was that the current hypothesis concerning effects of greenhouse gases on arctic behavior is probably simplistic and may be quite wrong. The public has been told repeatedly that a result of increased greenhouse gases would be a substantial rise in sea level due to melting of polar ice. A related statement frequently made is that the increase in polar temperatures would be substantially greater than those of global averages. For example, one estimate is that an average rise of 2°C would be accompanied by a 10°C increase in the Arctic. That estimate may or may not adequately take into account climatic feedback mechanisms. At the symposium this point was raised implicitly by John T. Andrews, who stated that the Greenland Ice Sheet and the Laurentide Ice Sheet advanced during a period of warm water influx into Baffin Bay at the end of the last interglaciation.

The vapor pressure of water is quite sensitive to temperature. Condensing moisture in the form of snow provides a surface cover that highly reflects solar energy leading to a regional cooling. The albedo (reflectivity) of ordinary soil is about 0.1. The albedo of snow is about 0.8. At present, some of the arctic land areas that have averaged annual temperatures of about −14°C receive only 10 centimeters of total H_2O per year. Most of the time the surface is bare and is a good absorber of solar heat. Were more precipitation to occur, the total heat absorbed by the surface would decrease. With greater moisture in the air, there would be more clouds. The net effects of these are controversial. Some say that more clouds would reflect more energy away from the earth. Others point out that added moisture would enhance a greenhouse effect in the Arctic. In any event, the factors controlling arctic climate are complex.

One of the obstacles to confidence in predicting the future of the arctic climate is an imperfect knowledge of the past. We know that 70 million years ago, the climate was mild and the Arctic Ocean was ice-free. Sediments formed about 5 million years ago contained glacially related materials. We know little about what happened in the long interval, and knowledge concerning more recent events is sketchy. No long cores have been obtained from the Arctic Ocean. The impediment is the perennial ice sheet that covers most of that ocean. The thickness is usually about 3 to 4 meters, and the sheet tends to keep moving. At the geographic North Pole, the depth of the ocean is about 3500 meters.

Our best source of evidence concerning the last million years is found in near-shore sediments, and particularly on fossil-bearing terraces. Molluscan fossils are particularly useful. Different molluscan species have different temperature affinities. In addition, they contain partially hydrolyzed proteins. The degree of racemization of isoleucine is a function of times and temperatures. The shells also contain strontium as a trace element which provides a dating potential. The ratio of ^{87}Sr to ^{86}Sr in seawater has changed monotonically over the last several million years. For events during the past 40,000 years ^{14}C dating can be applied. Other types of fossils are being studied and additional dating methods employed. Measurements of ratios of ^{18}O to ^{16}O in ice are useful in determining temperatures at which atmospheric moisture was converted into ice. Oxygen isotope ratios of shells reveal temperatures present during their formation.

The importance of understanding the past, present, and future of the arctic climate requires that support for such activities have a top priority. Desirable efforts include more studies of fossils, an international program of deep drilling in the Arctic, more weather monitoring, and additional satellite surveillance of the polar region.—PHILIP H. ABELSON

*"The Arctic: A New Key to World Climate and Resources," organized by P. W. Barnes and K. A. Kvenvold of the U.S. Geological Survey, Menlo Park, CA, and held on 19 January 1989 in San Francisco, CA.

1988 Ties for Warmest Year

The man who last summer said the greenhouse warming is here, James Hansen of the Goddard Institute for Space Studies, also said that, barring an improbable event, 1988 would be the warmest year on record. Well, he was right about 1988, but only barely. A consortium of British climatologists announced at the end of January that the globe's average temperature for 1988 was 0.34°C above that of the 1950–79 reference period. The past year thus noses out 1987, at 0.33°C above the reference, for the honor of warmest year in the 100-year record of instrumentally recorded global temperatures. But it is only a titular honor. "It's above the previous year," says Philip Jones of the University of East Anglia, but considering the inherent errors "it's not any different than the previous year." The year 1988 will have to settle for a tie.

Nineteen-eighty-eight does continue the run of warm years in the 1980s, according to the British group, which is composed of Jones and David Parker of the Meteorological Office in Bracknell and their colleagues. This decade lays claim to the six warmest years in the instrumental record, as analyzed for land by the East Anglia group and for sea surface temperatures by the Met Office group.

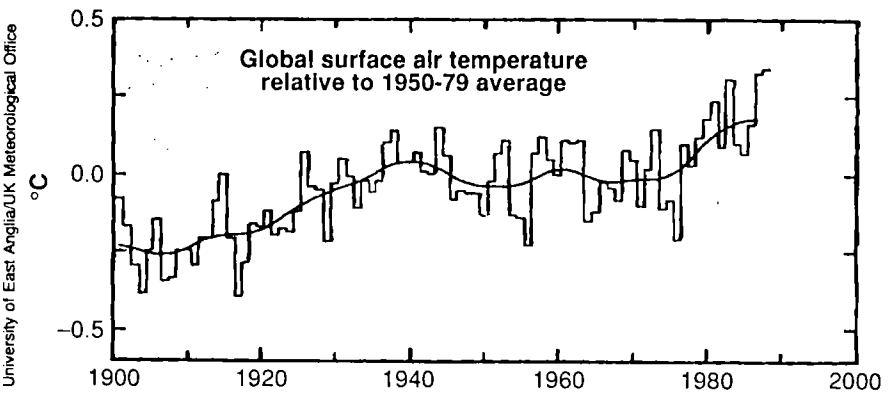
That the year managed even a tie might be taken as a sign of the robustness of the current surge of warming. Hansen's "improbable event" materialized last spring in the form of a sudden cooling of the tropical Pacific Ocean at the end of the 1986–87 El Niño (*Science*, 26 August 1988, p. 1037). It was a strong cooling, or La Niña, and the first major cooling since 1975 even though such coolings had recurred about every 4 years on average during the past century. Nineteen-seventy-five was also, perhaps only incidentally, the beginning of the current surge of global warming. There is an approximate 6-month lag between the beginning of a La Niña and its effect on global temperatures, but 1988 still "shouldn't have been as warm as 1987," says Jones, all else being equal.

The thought that it may be the greenhouse effect that is making all else less than equal is on everyone's mind. The British are still cautious. "It's the multiyear and decadal trends, not the individual years, that are important," says Jones. "While this [trend] is consistent with the theory, it can't be taken as unambiguous proof. We still need more warm years before we can say we've detected an effect."

This year should offer an interesting test. The global temperature was dropping toward the end of last year, especially at low latitudes, as La Niña took effect. And 1989 will likely be a La Niña year from beginning to end. On the assumption that only La Niña will be cooling the globe, Jones "would expect 1989 to be about 0.2°C colder than 1988," or still about 0.15°C above the reference period.

Another warm year in the 80s, in the face of La Niña cooling, would certainly impress climatologists, but it would not convince them. The cautious attitude pervading the climate community can even at times temper Hansen's confidence in his claimed detection of a greenhouse warming in 1988. Writing in the *Journal of Geophysical Research* last August, with seven coauthors, he concluded that "The greenhouse warming should be clearly identifiable in the 1990s." Perhaps in several years, when the next La Niña again tests the robustness of the warming trend, the consensus could shift.

■ RICHARD A. KERR



The warming trend continues. *The century-long global warming of about 0.5°C has had its ups and downs, the latest upturn coming in the mid-1970s.*

MEMORANDUM

FOR: SENATOR GORE

FROM: MIKE NELSON THROUGH RICK ADCOCK

RE: HEARING ON THE ROLE OF METHANE IN GREENHOUSE WARMING

February 27, 1989

As you know, the most important greenhouse gases are carbon dioxide, chlorofluorocarbons, methane, nitrous oxide, and tropospheric ozone. Of these, methane is the least understood. Methane is increasing rapidly in the atmosphere and yet it has been difficult to determine where it is all coming from. There are so many different sources and sinks of methane that it is difficult to measure the contribution of each one.

Methane is produced by wetlands, rice paddies, landfills, termites, cows and other ruminants. Deforestation leads to increased methane production because methane is produced when wood is burned and because of the increased number of termites on cleared land. Some of it is also released from natural gas pipes and coal mines. Another source may be permafrost in the polar regions. The contribution of each source is not very well-determined. How the importance of each source and sink is changing is even less well-determined.

Likewise, the fate of methane in the atmosphere is poorly understood. Much of it reacts with hydroxyl radicals. Some of it makes it to the stratosphere where ultraviolet radiation breaks it down. The amount of methane in the atmosphere may be increasing due to increased emissions from sources, from less methane being absorbed in sinks, or both.

ARCHITECTURE OF THE HEARING

The hearing provide a focused look at the sources and sinks of methane and its effect on global climate. It will provide a chance to examine some of the positive feedback mechanisms that involve methane. For instance, there is methane trapped in the frozen permafrost of the Arctic. If global warming accelerates, more permafrost would melt, leading to increased methane emissions and more global warming. Such runaway warming would be an environmental nightmare. At the hearing, you could examine the evidence for and against such a phenomenon.

The organization of the hearing would be relatively simple. Lead off with a witness to summarize the effects of methane in global warming and why we need to know where it's coming from. Then have witnesses to discuss what we know about each of the different postulated sources of methane. In addition to studies which try to measure methane emissions in

wetlands, rice paddies, and permafrost, there are several useful studies which have examined the isotopic composition of the methane in the atmosphere and in ice cores. Unfortunately, there is still a lot of debate about what the data all means.

RESULTS

This hearing will educate the members and the public about the threat of methane and identify some of the sources which may need to be controlled. It will identify other areas of research that need to be pursued.

POSSIBLE DATES

It would probably be best to develop this hearing in parallel with the global warming hearing and hold it during the third week in April.

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

Subcommittee on Science, Technology, and Space

Witness List*

Hearing on

Arctic and Antarctic Ozone Depletion

Thursday, February 23, 1989, 9:30 a.m.

in Room SR-253 of the Russell Senate Office Building

Panel 1 - Scientists from the Arctic Ozone Expedition

(2) Dr. Robert T. Watson, Earth Science and Applications Division, National Aeronautics and Space Administration, Washington, DC 20546

(3) Dr. Adrian F. Tuck, Aeronomy Lab, National Oceanic and Atmospheric Administration, Boulder, CO 80303

(1) Dr. Susan Solomon, Aeronomy Lab, National Oceanic and Atmospheric Administration, Boulder, CO 80303

Panel 2 - Manufacturers and Users of Chlorofluorocarbons

Dr. Joseph Glas, Director, Freon Products, E.I. DuPont, Inc., Wilmington, DE 19898

Mr. Robert Traflet, President, Fluorine Products, Allied-Signal, Inc., Morristown, NJ 07962

Mr. Arnold Braswell, President, Air Conditioning and Refrigeration Institute, Arlington, VA 22209

*Not necessarily in order of appearance

224-0580

FACSIMILE REQUEST AND COVER SHEET

TO: Rich Adcock / Sen. Gore's office

DATE: 2/27/89

OFFICE PHONE: 224-4944

NUMBER OF PAGES TRANSMITTED (Including Cover Sheet):

5

FROM: Global Change Division
Office of Atmospheric and Indoor Air Programs
Office of Air and Radiation
U.S. Environmental Protection Agency
401 M Street, SW (ANR-445)
Washington, D.C. 20460
Fax Number: 202-382-6344
Confirmation Number: 202-382-4036

Bob Kwartin

PHOTOCOPY
PRESERVATION

Questions for Mr. Braswell:

1. Do your members believe that there will be delays in choosing energy-efficient CFC substitutes if NIST does not alter its schedule for producing high quality thermophysical data, but instead continues to give priority to use of its equipment to research being conducted for the Gas Research Insitute on gas metering and for NASA/DoD on the space aeroplane?

2. Is ARI concerned about how various consortia of other nations sponsored by governments will effect the competitiveness of US industry in air conditioning and refrigeration?

3. Could the industry absorb about 20-30 million dollars of R&D funds from the proposed fees being put on regulated CFCs?

PHOTOCOPY
PRESERVATION

Questions for Mr. Glas:

1. What tests have you conducted which show that R-23 or R-32 could not be a substitute for HCFC-22 with equipment redesign? Please provide detailed data to back up your statement that "we know of no viable substitute for HCFC-22".

2. Is DuPont retracting its comment to some user groups that it plans to stop selling them CFC-11 or -12 at a certain date?

3. Has DuPont increased its shipments to Igloo for the purpose of stockpiling reported in the trade press and eliminated shipments to other aftermarket distributors for the auto market?

4. How much has DuPont raised the price of CFC 11, 12, 113, 114, 115 or blends among them? How much have you increased 1988 sales? How much have you increased HCFC22 sales? How much have you raised the price of HCFC22?

5. You claimed you have done everything possible to introduce substitutes, yet so far you have not released all thermophysical data compiled on the full range of substitutes you have investigated. How do you reconcile them and your statement? How soon will you release this vital information?

6. Why haven't you started 2-year inhalation studies of R-124 and R-125 if you believe these compounds can contribute to the solution?

7. Why don't DuPont and other chemical companies agree on a crash program of thermophysical testing since you stand to profit off new chemicals?

PHOTOCOPY
PRESERVATION

Question for Mr. Traflet:

1. Why hasn't Allied released all thermophysical data on substitutes it has investigated to user groups so they can evaluate the merits of various refrigerants and mixtures on their own?

PHOTOCOPY
PRESERVATION

Question for Dr. Watson:

1. Does the observed depletion at 19-20 km at many latitudes in any way support the hypothesis that heterogeneous chemistry may be taking pklace in the so-called "aerosol layer" of the ozone layer? What is the magnitude and timing of all of NASA's efforts to resolve this issue?

PHOTOCOPY
PRESERVATION

Meeting Memo

Time/Date: 5 p.m. Thursday, Feb. 23 NOTE LOCATION OF INTERVU
253 RUSSELL S.O.B.

Participants: Ned Potter, ABC News (and camera crew)

Staff: Marla

Purpose of meeting: Potter is working on 4-min piece (for the "American Agenda" segment of World News Tonight) on the ozone problem. He will cover the hearing Thursday morning and is trying to also get interviews with the DuPont and corporate types.

Recommendation:

***As always, be concise. Plain language. Imagine you're talking to real people, trying to convince them they should care about this.

***Stress your leadership, foresight on these issues.

***Focus on key points: implications of ozone loss, global nature, need to develop CFC alternatives (real-life changes in airconditioning, refrigeration, etc).

Background

##

CFCs
CCl_4
Methyl Chloroform — go back to atmosphere of 1970s

1 yr of Cl today takes 10 years to get it out

"TIME IS OF THE ESSENCE"

BUT DON'T FOCUS ON FIVE YEARS

OF THE ESSENCE

Bob WATSON — CALL $20 - 10^{00}$ to
POSE QUESTIONS —
703 230-8034

DO NOT NAIL THE QUANTITATIVE —

CCl_4 + methyl chloroform — not in MP — do we need to regulate?

MEMORANDUM
February 17, 1989

TO: DEMOCRATIC MEMBERS, SENATE COMMERCE COMMITTEE
FROM: MIKE NELSON AND PENNY DALTON
RE: FEBRUARY 23 HEARING ON ARCTIC AND ANTARCTIC OZONE DEPLETION

On Thursday, February 23, 1989, the Science, Technology, and Space Subcommittee will hold an oversight hearing on the depletion of the stratospheric ozone layer by chlorofluorocarbons (CFCs) and other man-made chemicals. The hearing will be held at 9:30 a.m. in Room 253 of the Russell Building. Senator Albert Gore, Jr., will chair the hearing.

The subcommittee will be briefed by the scientists who led a recently-completed research expedition to look for an Arctic ozone hole. Their findings indicate that the same chemicals that are responsible for the dramatic depletion of stratospheric ozone in the Antarctic ozone hole are also present over the Arctic. Thus, there is the potential for major depletion of ozone in the Arctic. Just a few percent depletion of the ozone layer would lead to increased ultraviolet (UV) radiation which could cause millions of additional cases of skin cancer and cataracts in the decades ahead. In addition, the increased UV radiation could cause serious damage to crops, forests, and marine ecosystems. Changes in the composition of the stratosphere can also lead to changes in stratospheric temperatures and global climate.

A second panel, consisting of representatives of companies which manufacture and use CFCs, will discuss the progress that has been made in finding replacements for CFCs and the problems which remain.

BACKGROUND

In 1974, Dr. Sherwood Rowland and Dr. Mario Molina, two chemists at the University of California, first pointed out that CFCs could cause depletion of the stratospheric ozone layer which shields the earth from harmful UV radiation. They found that CFCs are very stable and last for decades in the atmosphere. However, when they reach the stratosphere, 10 to 20 miles above the earth, UV radiation causes the CFC molecules to break apart, releasing chlorine, which in turn causes depletion of the ozone layer. A single atom of chlorine can destroy 100,000 molecules of ozone. Using simple chemical models, Rowland and Molina predicted that at current rates of CFC emissions, measurable amounts of ozone layer depletion would become apparent some time in the next century.

Impact of Ozone Depletion. The impact of increased UV radiation due to ozone depletion has not been adequately studied. There is scientific consensus that a few percent depletion of the ozone layer would lead to millions of additional cases of skin cancers and cataracts each year worldwide. In the United States this could mean thousands of additional deaths annually. Another concern is evidence that enhanced UV radiation could cause major damage to marine ecosystems. Some species of the tiny plankton that form the base of the marine food chain appear to be particularly sensitive to UV radiation. Changes in plankton productivity could decrease harvests of fish worldwide. Enhanced UV radiation can also decrease yields of several major crops.

Uses of CFCs. The three most important CFCs are: CFC-11, which is used in large air conditioning and refrigeration systems and in the manufacture of plastics and foam; CFC-12, which is used in household and automobile air conditioners; and CFC-113, which is used to clean computer chips. In the past, CFCs were used as a propellent in aerosol spray cans. In response to Rowland and Molina's theory, the United States banned the use of CFCs in aerosol cans in the mid-1970s. This led to a nearly 50% reduction in the use of CFCs in the United States. Unfortunately, other countries did not follow the U.S. lead and world CFC production levels are now at their highest level ever.

By the mid-1980s, scientific research confirmed that CFCs do pose a threat to the ozone layer. However, because ozone concentrations in the ozone layer vary naturally by 5-10% from year to year, there was no clear evidence that ozone depletion was occurring.

Discovery of the Antarctic "Ozone Hole". In 1985, British scientists in Antarctica reported that stratospheric ozone concentrations during the spring over Antarctica had dropped by more than 40%. This dramatic reduction had not been predicted by Rowland and Molina's theory and led to a flurry of research activity. Analysis of data from a NASA satellite confirmed the existence of the Antarctic ozone hole. In 1986 and 1987, the National Ozone Expeditions, led by Dr. Susan Solomon discovered that CFCs were responsible for the ozone hole. Researchers found that ice crystals in polar stratospheric clouds caused complicated "heterogenous" chemical reactions which are much more effective at destroying the ozone layer than the simple chemical reactions modelled by Rowland and Molina. The ice in the clouds serves as a catalyst for speeding up the destruction of ozone by CFCs. Fortunately, these clouds can only form during the long polar nights at temperatures colder than -77 degrees Celsius. The ozone depletion process also requires sunlight. Thus, rapid ozone depletion does not begin until the sun returns to Antarctica in the spring, triggering the dramatic formation of the ozone hole.

Montreal Protocol. By 1985, the scientific evidence was compelling enough to convince the major CFC-producing nations to agree, in the Vienna Convention, to the need for global controls

on CFC production. The Montreal Protocol followed in September, 1987, and was ratified by most of the 24 signatory nations by the end of 1988. The Protocol requires that, beginning in mid-1989, developed countries freeze their CFC production and consumption at 1986 levels and cut production by 50% over the next 10 years. Production of halons, another family of ozone-depleting compounds which are used in fire extinguishers, is frozen at 1986 levels. Developing countries are given a ten-year delay in implementing production controls. They are free to increase CFC production until 1996.

Arctic Ozone Expedition. Last winter, scientists working in Norway, Greenland, and the Canadian Arctic, detected ozone-depleting chemicals in the stratosphere similar to those found in the Antarctic ozone hole. To investigate the possibility of an Arctic ozone hole, more than 100 researchers organized the international Airborne Arctic Stratospheric Expedition which started early in January, 1989. U.S. researchers from the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the National Science Foundation (NSF) were involved. In addition, scientists from the United Kingdom, Canada, Norway, and several other countries took part.

Using U-2 aircraft, a modified DC-8 airplane, balloon observations, and ground observations, researchers found many of the same ozone-depleting chemicals in the Arctic stratosphere that are present in the Antarctic ozone hole. However, thus far, no extensive ozone depletion has been detected. During the next two months, as spring approaches and sunlight returns, it is possible that an Arctic ozone hole will form. Researchers will continue their monitoring to see if it does.

Global Ozone Depletion. Ozone depletion at the poles is contributing to a worldwide decrease in ozone concentrations. In addition, ozone depletion is occurring at lower latitudes, albeit at a slower rate. Last March, the international Ozone Trends Panel, chaired by Dr. Robert Watson of NASA, reported that since 1969 there has been a 2-3% depletion of the ozone layer over the United States. During the winter months, ozone concentrations were 2-6% lower. These measurements indicated that ozone depletion was occurring 2-3 times faster than previously recognized. This is thought to be due in part to unexpected ozone depletion over the Arctic and Antarctic.

Calls for additional cuts in CFC production. The unexpectedly high rates of ozone depletion have led to calls for cuts in CFC production that are larger and faster than those stipulated in the Montreal Protocol. Last Congress, Senators Baucus and Chafee introduced S. 570 and S. 571, calling for cutting production of ozone-depleting CFCs and halons to 5% of 1986 levels by 1995. The bills also called for penalties for use of CFCs. In addition, Senator McCain introduced S. 2502, a bill to establish a task force charged with reducing federal government use of CFCs.

This year, Senator Gore introduced S. 201 which, along with other provisions, includes a call for a total ban on the production of the five most important ozone-depleting CFCs and halons by 1996. Three other ozone-depleting compounds would be banned by 2000. Senator Leahy has similar provisions in his S. 333. Both bills were referred to the Committee on Environment and Public Works.

The producers and users of CFCs are opposed to these rapid proposed cuts. They argue that a unilateral phase-out by the U.S. will put American industry at a competitive disadvantage vis-a-vis foreign companies. They also argue that it will take at least ten years to develop alternatives to CFCs, test their toxicity, build new production capacity, and adapt existing air-conditioning and refrigeration equipment to the new alternatives. Dupont and other companies have announced new compounds which can replace CFCs in some applications. Many of these new products consist of hydrofluorocarbons (HFCs) or mixtures of two or three liquids, sometimes including a small percentage of CFCs. Some industries, most notably the plastic and foam-blowing industries, have already taken steps to phase-out the use of CFCs. This will be more difficult in the refrigeration and air-conditioning sector.

POLICY QUESTIONS

What does the science tell us? The Arctic ozone expedition is providing more information about how ozone depletion occurs in the stratosphere. It is clear that CFCs are causing ozone depletion. However, there is still quite a bit of uncertainty about how fast ozone depletion will occur in the future.

Is the present research effort adequate? Will the present research effort provide the answers policy-makers need to make decisions on phasing out CFCs and other ozone-depleting substances? Research is needed not only on CFCs but also on halons and other compounds which destroy ozone. CFCs and halons are present in only a few parts per billion in the atmosphere and yet are causing worldwide environmental concerns. Are there other gases in the atmosphere about which we need to worry? The chemical companies are particularly concerned that they will develop CFC alternatives which will be found to be even worse for the environment than the CFCs they replace.

Is the federal research effort well-coordinated and well-planned? The Arctic and Antarctic ozone expeditions are good examples of how NOAA, NASA, and NSF can work together on global change research. Are these expeditions the rule or the exception? In January, Senator Hollings introduced S. 169, the National Global Change Research Act, to ensure such interagency cooperation.

Can federal research and development programs assist in the transition to CFC alternatives? Several million dollars are spent each year by the National Institute of Standards and Technology

(NIST, formerly the National Bureau of Standards), the Department of Energy (DOE), and the Environmental Protection Agency (EPA) for R&D on CFC alternatives and on refrigeration and air-conditioning equipment which uses them. Last year, Senators Hollings, Rudman, and McCain worked together to get an addition $250,000 appropriated for research on CFC alternatives at NIST. Has this effort been of use to CFC manufacturers and users? Should it be expanded?

How quickly can CFC production be phased down? What will the cuts required by the Montreal Protocol mean to industry? What would be the impact of an accelerated phase-out? In addition to regulating production of CFCs, several proposed bills call for fees for CFC use. The EPA is considering auctioning off CFC production rights. Predictably, CFC manufacturers and users oppose such proposals.

WITNESSES

The first panel of witnesses will consist of researchers from the Airborne Arctic Stratospheric Expedition. **Dr. Robert Watson** is head of NASA's Upper Atmosphere Research and Tropospheric Chemistry Branch. He was program scientist for the Arctic expedition and has been very involved in research on the Antarctic ozone hole. **Dr. Adrian Tuck**, co-leader of the expedition, is an atmospheric chemist from NOAA's Aeronomy Laboratory in Boulder. **Dr. Susan Solomon** is also from NOAA's Aeronomy Lab. She led the National Ozone Expeditions to the Antarctic which determined the cause of the Antarctic ozone hole. She was also part of the Arctic expedition. The panel will review the findings of the Arctic expedition, discuss the most recent findings from the Antarctic, and provide an update on research on global ozone depletion.

The second panel of witnesses consists of **Dr. Joseph Glas**, Director of Dupont's Freon Division, and **Robert Traflet**, President, Fluorine Products at Allied-Signal. Dupont and Allied-Signal are two of the largest producers of CFCs and are spending tens of millions of dollars developing alternatives to CFCs. In addition, **Arnold Braswell**, President of the Air-conditioning and Refrigeration Institute (ARI), will represent manufacturers of large air-conditioners and chillers for buildings and commercial refrigeration units. He will discuss the efforts that ARI members are making to replace CFCs in their equipment. Several other industry user groups have asked to submit testimony for the record.

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

Subcommittee on Science, Technology, and Space

Witness List*

Hearing on

Arctic and Antarctic Ozone Depletion

Thursday, February 23, 1989, 9:30 a.m.

in Room SR-253 of the Russell Senate Office Building

Panel 1 - Scientists from the Arctic Ozone Expedition

Dr. Robert T. Watson, Earth Science and Applications Division, National Aeronautics and Space Administration, Washington, DC 20546

Dr. Adrian F. Tuck, Aeronomy Lab, National Oceanic and Atmospheric Administration, Boulder, CO 80303

Dr. Susan Solomon, Aeronomy Lab, National Oceanic and Atmospheric Administration, Boulder, CO 80303

Panel 2 - Manufacturers and Users of Chlorofluorocarbons

Dr. Joseph Glas, Director, Freon Products, E.I. DuPont, Inc., Wilmington, DE 19898

Mr. Robert Traflet, President, Fluorine Products, Allied-Signal, Inc., Morristown, NJ 07962

Mr. Arnold Braswell, President, Air Conditioning and Refrigeration Institute, Arlington, VA 22209

*Not necessarily in order of appearance

NEWS

from the U.S. Senate

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

Senator Ernest F. Hollings, Chairman

101st Congress - First Session

For Immediate Release: February 16, 1989 101-12

COMMITTEE TO HOLD A HEARING ON ARCTIC AND ANTARCTIC OZONE DEPLETION

Senator Ernest F. Hollings (D-S.C.) Chairman of the Senate Committee on Commerce, Science, and Transportation, today announced the Subcommittee on Science, Technology, and Space will hold a hearing on Arctic and Antarctic ozone depletion.

Senator Albert Gore Jr., (D-TN), Subcommittee Chairman, will chair the hearing, which is scheduled for Thursday, February 23, at 9:30 a.m. in Room SR-253 of the Russell Senate Office Building.

"The ozone layer protects all life on earth from harmful ultraviolet radiation," said Senator Gore. "This ozone layer is under attack from chlorofluorocarbons and halons, chemicals which are manmade. The Environmental Protection Agency recently projected that with present growth rates in the emissions of these chemicals, there will be an additional 40 million skin cancer cases and an additional 800,000 deaths of Americans who are alive today and those born within the next 88 years.

"The best way to protect the public is to preserve the environment by limiting the production of ozone-depleting chemicals. There is no real excuse for not doing that. We can't waste any more time -- the time to act is now."

The discovery of the Antarctic ozone hole in 1985 led to worldwide alarm over rates of stratospheric ozone depletion. This year's Arctic ozone expedition, composed of more than 100 researchers and scientists, have been looking for evidence of a similar "hole" over the Arctic. Three of the leaders of the scientific team will brief the Subcommittee for the first time on their findings. The team is expected to confirm that chlorofluorocarbons (CFCs) are causing ozone depletion over the Arctic and the Antarctic. In addition, they will discuss the implications of their findings for protecting the ozone layer worldwide.

Although the United States banned the use of CFCs in non-essential aerosols more than a decade ago, their use continues in air-conditioners, refrigerators, insulation, and foam packaging. The hearing will also focus on the challenges that cutting production and finding substitutes for CFCs will pose to manufacturers and industries now using these chemicals.

-more-

Witnesses expected to testify include Dr. Robert T. Watson, Earth Science and Applications Division, National Aeronautics and Space Administration; Dr. Adrian F. Tuck, Aeronomy Lab, National Oceanic and Atmospheric Administration; Dr. Susan Solomon, Aeronomy Lab, National Oceanic and Atmospheric Administration; Dr. Joseph Glas, Director, Freon Products, E.I. DuPont, Inc.; Dr. Marilyn I. Montgomery, Vice President and General Manager, Genetron Products, Allied-Signal; and Arnold Braswell, President, Air Conditioning and Refrigeration Institute.

For more information please contact Mike Nelson or Penny Dalton of the Majority Staff at 224-9360 or Tiger Joyce of the Minority Staff at 224-8172. Media please contact Emilio Pardo at (202) 224-0411.

-30-

United States Senate
COMMITTEE ON
COMMERCE, SCIENCE, AND TRANSPORTATION
WASHINGTON, DC 20510-6125
OFFICIAL BUSINESS

Ernest F. Hollings
U.S.S.

22480-3
MR. ROY NEEL
OFFICE OF SENATOR GORE
U. S. SENATE
WASHINGTON, DC 20510

MEMORANDUM

FOR: SENATOR GORE

FROM: MIKE NELSON

RE: FOLLOW-UP ON OZONE DEPLETION HEARING

February 23, 1989

There were several items you had requested concerning today's ozone depletion hearing. Rick and I didn't have a chance to get them to you before the hearing began, but I wanted to get them to you now.

Attached are:

1. Revised table on substitutes to CFCs.

2. Memo on reaction rates of ozone depletion

3. Memo and article about how UV radiation in the Antarctic ozone hole is not a human health hazard.

4. Memo on plankton productivity and carbon dioxide absorption in the oceans and forests (by Penny Dalton).

5. Copy of Journal of Commerce article on the hearing

If you have any particular questions for the record you would like asked, just tell me.

Just call if there's anything else I can provide.

MEMORANDUM

FOR: SENATOR GORE

FROM: MIKE NELSON

RE: PROMISING CFC SUBSTITUTES

23 February 1989

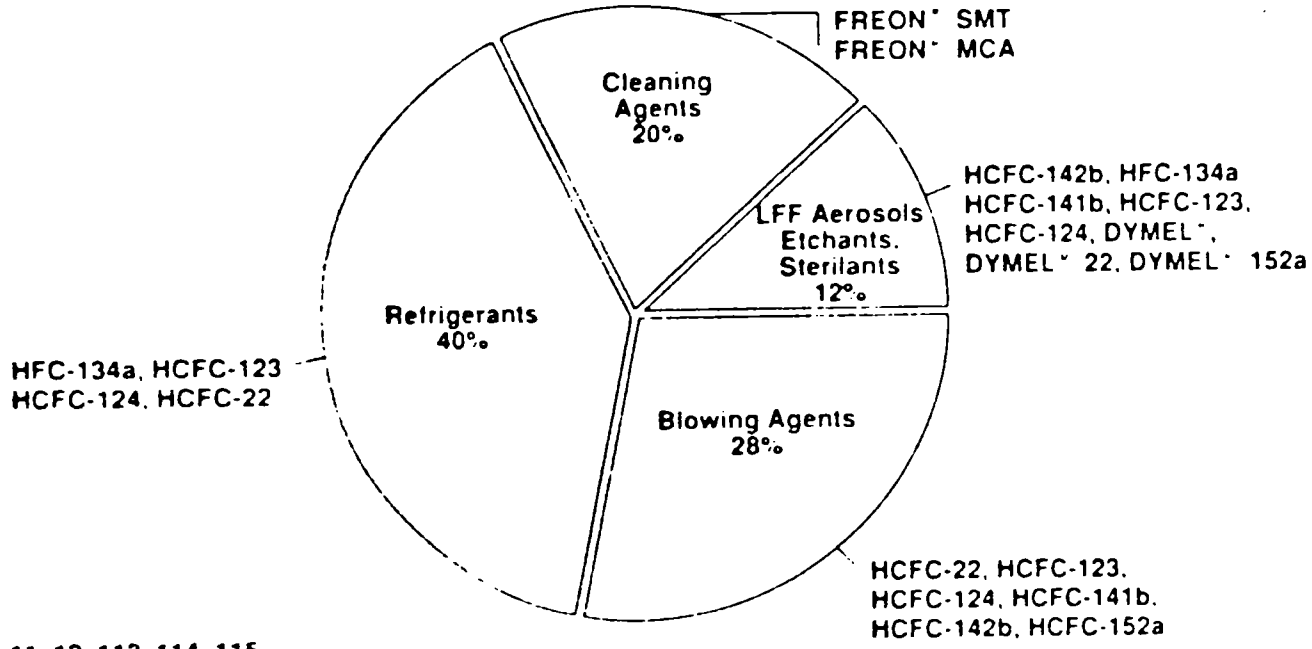
Each CFC has hundreds of different uses. No one substitute will work in every application for which a given CFC is used. There are many applications where CFC alternatives are not yet available. The table below summarizes the most important substitutes, their uses, and the problems that remain in their development. There are dozens of other substitutes being evaluated and many will find use in specialized applications. The table is based on the Science article I gave you, Dupont's testimony, and EPA testimony on CFC substitutes. The attached figure is from Dupont's testimony.

A note on nomenclature: As you know, CFCs and their substitutes are not referred to by their chemical formulae but by informal names like CFC-12 and HFC-134a. Unfortunately, there is some confusion when it comes to naming many of the CFC replacements. When American chemical companies refer to HFCs they mean compounds containing only hydrogen, carbon, and fluorine, which do not deplete the ozone layer. According to the companies, if you have chlorine as well you call it an HCFC. These do deplete the ozone, but have only 5-10% the ozone depletion potential of CFCs. Both are greenhouse gases, although less harmful that CFCs. Unfortunately, others group both families of compounds under the heading HFCs. To make it even more confusing, the refrigeration and air conditioning industry doesn't use the term CFC at all. For instance, they call CFC-11 refrigerant-11, or R-11 for short.

SUMMARY OF CFC SUBSTITUTES

CFC and its uses	Most promising substitute and its uses	Problems with substitute
CFC-11 foam blowing large A/C large refrigerators	HCFC-123 foam blowing some refrigerators	Foam made with HCFC-123 has lower insulating properties New foam blowing techniques need to be developed
CFC-12 small A/C refrigerators car A/C large refrigerators large A/C systems plastics and foam	HFC-134a small air conditioners refrigerators car air conditioners	Toxicity tests incomplete Difficult to make Equipment will have to be retrofitted Not compatible with oils and gaskets used in equipment Leads to lower energy efficiency in existing equipment
	HCFC-22 is replacing both CFC-11 and 12 in large refrigeration and A/C systems It is also used in foam blowing and foam food containers	Production process still being perfected Requires retrofitting Depletes the ozone layer (only 5% as harmful as CFC-11) Greenhouse gas Not good for making insulating foam
CFC-113 chip cleaning	Several competing alternatives HFC-134a looks good	The most promising alternative, HFC-132b, turned out to cause sterility in rats. Many alternatives dissolve plastics on chips Toxicity tests incomplete

U.S. CFC Market*
Where Potential Alternates May Meet Market Needs



* CFCs-11, 12, 113, 114, 115

Note on reaction rates of ozone depletion

"Chemical kinetics" is the study of reaction rates. Since reaction rates can determine whether a commercial chemical manufacturing process is profitable, a lot of effort has gone into understanding chemical kinetics. Most reaction rates are either linear (double concentration of the reactants and you double the rate) or they're second-order (double the concentration of the reactant and you quadruple the reaction rate). The way the reacting molecules collide to form a new molecule determines the type of reaction rate. In a complicated, multi-step reaction, the slowest ("rate-limiting") step determines the type of reaction rate.

In the case of polar ozone depletion the reaction obey a second-order rate law. The relevant reaction is:

$$ClO + ClO \longrightarrow Cl_2O_2$$

$$Cl_2O_2 + \text{sunlight} \longrightarrow 2Cl + O_2$$

$$Cl + O_3 \longrightarrow ClO + O_2$$

(ClO is chlorine oxide, Cl_2 is a chlorine molecule, Cl is a free chlorine atom, O_3 is ozone, and O_2 is oxygen)

To understand why this reaction obeys a second-order rate law, consider the reaction

$$A + B \longrightarrow C$$

If A and B are present in about equal amounts and we double the amount of A, a collision between A and B becomes twice as common. The same applies to doubling B. So if we double the concentrations of both, we get four times as many collisions and four times as much product (C). The first reaction in the ozone depletion process is like this example with A = ClO and B = ClO, so doubling ClO quadruples the reaction rate.

MEMORANDUM

FOR: SENATOR GORE

FROM: MIKE NELSON

RE: UV RADIATION IN THE ANTARCTIC OZONE HOLE

February 22, 1989

As I mentioned in our meeting today, the danger of UV radiation to humans in Antarctica is no worse than that for people in mid-latitudes, even when ozone levels are a low as they can possibly get. This is because the sun is very close to the horizon during the Antarctic spring when the ozone hole is at its worst. Sunlight (including UV radiation) must travel through much more atmosphere because it comes in at such a low incident angle. Although there's less ozone in the atmosphere, this "thicker filter" makes up for the lost ozone.

The same thing happens at sunset. The atmosphere absorbs more blue light that red light. You don't notice this when the sun is overhead, because the sun is coming straight through the atmosphere. But at sunset, light is passing through 10 to 20 times as much atmosphere, and all the blue light is filtered out, making the sun look red.

The attached article from Science calculates the amount of UV radiation people in Antarctica would be exposed to when the Antarctic ozone hole is at its worst. It's less than people in lower latitudes receive on a summer day. In addition, most people in Antarctica don't go around with much skin exposed. Thus, UV radiation is not a serious health hazard. It is a problem for the Antarctic phytoplankton since they aren't accustomed to much UV radiation at all.

Antarctic ozone hole

How much extra radiation from the sun hits Antarctica as a result of the ozone hole, and how does the solar irradiance there compare with the amount of ultraviolet light reaching the earth elsewhere? Each year in September (the start of spring in the Southern Hemisphere), the ozone hole begins to develop, in October ozone levels drop to a minimum, and in November the hole dissipates. Frederick and Snell calculated and compared ultraviolet irradiance at the earth's surface at McMurdo Station in Antarctica and levels at Miami, Florida, which is representative of a low to mid-latitude location (page 438). At McMurdo Station the sun is low in the sky (and has a high zenith angle), whereas over Miami the sun is high (and has a low zenith angle); thus, even when the ozone levels are most depleted, the amount of ultraviolet radiation reaching Antarctica is not much different from the amount that hits Miami at the summer solstice. Nonetheless, the increased radiation over Antarctica and the effective "longer summer" brought on by the ozone hole may cause problems for indigenous plants and animals that have adapted to a different environment.

Gulf Stream in the glacial age

First, a thick continental ice sheet formed, altering atmospheric circulation and global wind patterns; this led to a shifting of polar waters southward, causing the North Atlantic sea-surface temperature to cool, and, as a marker of these changes, the Gulf Stream flowed almost straight eastward toward Gibraltar (page 440). This is the sequence of events that, according to the atmospheric model of Keffer *et al.*, changed the global climate during the last ice age, which reached a maximum 18,000 years ago. The Gulf Stream today flows southwest to northeast from Hatteras off the Carolinas to the Norwegian Sea; the Gulf Stream and its extension, the North Atlantic Current system, demarcate the boundary between circulation patterns in the northern ocean (the subpolar gyre) and the more southern subtropical gyre. According to the model, the role of the ocean in the initiation of continental glaciation was a passive one.

Heart and sole

Eskimos in Greenland and villagers living in fishing communities in Holland and Japan have especially low incidences of cardiovascular disease; the fish oil in their diets has been credited with this health advantage. Fox and DiCorleto propose that when fish oils are ingested, plasma lipids are modified and then inhibit the production of a protein, platelet-derived growth factor–like protein (PDGFc), by endothelial cells (page 453). This proposal is supported by a study of the in vitro effects of fish oil extracts on endothelial cells, the cells in the artery wall that act as conduits for the exchange of material and information between the blood and the tissues. Endothelial cells that were treated with a fish oil extract stopped making PDGF. In vitro PDGF stimulates smooth muscle cell proliferation, and, therefore, if PDGF were inactivated in vivo, the proliferation of smooth muscle cells might be reduced; as a result, blood vessels would not thicken as they do in atherosclerosis and other cardiovascular diseases.

Fertilization events

Biochemical events that take place at the time of fertilization are similar to those that occur when a cell is activated by a neurotransmitter, a hormone, or light. This has been illustrated by experiments in which receptors for neurotransmitter are inserted into oocyte membranes (page 464). Messenger RNA molecules for one of two neurotransmitter receptors were injected into oocytes and, within a few days, the receptors were expressed on the oocyte surface. After the oocytes had been matured to eggs (a process brought about by addition of the hormone progesterone), stimulation of the egg with the matched neurotransmitter induced several electrophysiologic and morphologic phenomena that usually accompany fertilization (cover). Kline *et al.* propose that the neurotransmitters (experimentally) and the sperm (naturally) bind to receptors on the surface of the oocytes and cause an interaction with G proteins in the egg (by analogy with reactions that take place after other neurotransmitter-receptor interactions) that initiates the series of steps that produces activation.

Ecdysone as insecticide

The actions of ecdysone, the steroid hormone that induces molting in many invertebrates, can be mimicked with the insecticide RH 5849 (pages 467 and 470). Wing and colleagues report that, in cultured *Drosophila* cells and cell extracts and in larvae of tobacco hornworms, the actions of RH 5849 and ecdysone are qualitatively the same, and RH 5849 binds competitively to the ecdysone receptor. In the tobacco hornworms, RH 5849 was even more potent than ecdysone in inducing molting, either because it is more efficiently absorbed, more easily transported, or more stable than the natural hormone. Because RH 5849 can induce a premature and lethal molt, it or analogs could prove to be powerful "third generation" insecticides. In addition, these new nonsteroid substances are easier to synthesize than steroids and should be of use in studying the mode of action of ecdysone and the structure, function, and distribution patterns of ecdysone receptors.

The bottom lines

Black holes are now filling the silver screen. A simulation with the Cornell University supercomputer shows sequential stages by which clusters of movie stars collapse to form black holes (page 421).

Reports

Ultraviolet Radiation Levels During the Antarctic Spring

JOHN E. FREDERICK AND HILARY E. SNELL

The decrease in atmospheric ozone over Antarctica during spring implies enhanced levels of ultraviolet (UV) radiation received at the earth's surface. Model calculations show that UV irradiances encountered during the occurrence of an Antarctic "ozone hole" remain less than those typical of a summer solstice at low to middle latitudes. However, the low ozone amounts observed in October 1987 imply biologically effective irradiances for McMurdo Station, Antarctica, that are comparable to or greater than those for the same location at December solstice. Life indigenous to Antarctica thereby experiences a greatly extended period of summerlike UV radiation levels.

MUCH OF THE CONCERN OVER changes in the ozone layer centers on the biological importance of UV radiation (*1*). The spectral regions of primary interest for biological damage are the UV-B at wavelengths from 280 to 320 nm and, to a lesser extent, the UV-A from 320 to 400 nm. The reduction in total column ozone observed over Antarctica (or "ozone hole"), which develops in September and dissipates during November of each year (*2*), implies an increase in biologically effective UV radiation at the earth's surface. The large solar zenith angles characteristic of the polar regions usually imply small UV irradiances as compared with those at lower latitudes. However, when accompanied by a dramatic decrease in column ozone, it is not obvious how the springtime irradiances compare with middle latitude values or to radiation levels typical of an unperturbed Antarctic summer solstice.

One concern involves possible eye damage to researchers who visit Antarctica for extended periods of time. A relevant comparison for this case is between Antarctic UV levels and the maximum irradiances that humans encounter at low to middle latitudes. A second, and potentially more significant, concern centers on the response of indigenous Antarctic life to enhanced UV irradiances. Many organisms appear to develop only the minimum defenses necessary to tolerate the UV radiation levels in which they have evolved (*3*). Adverse responses may occur, depending on the dose-response relation, if the irradiance exceeds natural levels for a prolonged time. A relevant comparison here is between UV irradiances encountered during an "ozone hole" and those typical of an Antarctic summer solstice with an unperturbed ozone amount.

We report calculations of UV irradiance at the earth's surface for McMurdo Station, Antarctica (McMurdo, 78°S), during depleted ozone and normal ozone conditions. We compare these irradiances with calculations for the latitude of Miami, Florida (26°N), on 21 June and McMurdo on 21 December. Results for 26°N should be viewed as representative of low to middle latitude sites in general, rather than being specific to Miami. The radiative transfer equations to be solved have been discussed in detail elsewhere (*4*). The only significant change from our earlier model involves a correction to account for the sphericity of the atmosphere, which is essential for application to the large solar zenith angles encountered at high latitudes. The radiative transfer model includes all orders of scattering, absorption by ozone, and reflection from a lower boundary. We assume clear skies and a surface albedo of 0.95, which is appropriate to clean Antarctic snow and ice cover. The irradiance calculations encompass wavelengths from 295 to 400 nm and use recommended values of the extraterrestrial solar irradiance, ozone absorption cross sections, and Rayleigh scattering cross sections (*5*).

The downward irradiances at the earth's surface for local noon as functions of wavelength for Miami on 21 June and McMurdo on 21 December are shown in Fig. 1A. The column ozone values adopted here are 280 and 350 Dobson units (DU), respectively (*6*). We selected these ozone amounts based on measurements from the Nimbus 7 Solar Backscatter Ultraviolet radiometer for the year 1979. The solar zenith angles are 2.3° at Miami and 54.2° at McMurdo. At wavelengths greater than 330 nm, the irradiance

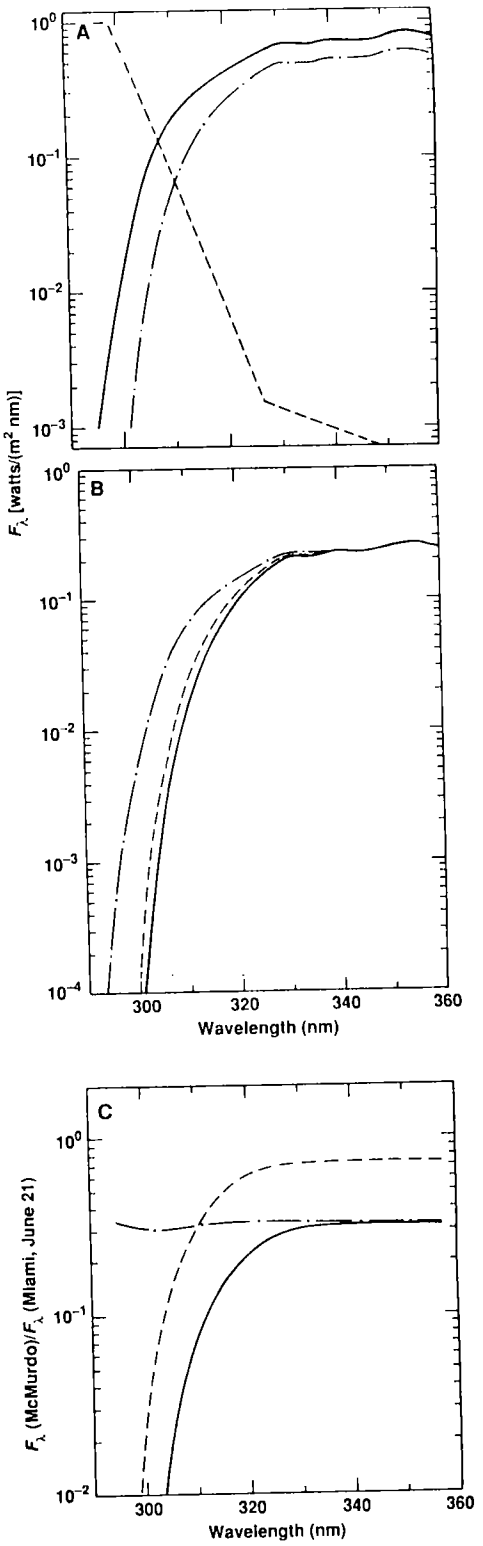


Fig. 1. Downward solar irradiance (F_λ) reaching the earth's surface at local noon as a function of wavelength. (**A**) Results for the latitude of Miami, Florida, on 21 June (solid line) and for McMurdo on 21 December (dot-dash line). Dashed line is the erythema action spectrum in relative units. (**B**) Results for McMurdo on 5 October with a solar zenith angle of 71.6°. Curves appear for ozone column abundances of 315 (solid line), 250 (dashed line), and 110 DU (dot-dash line). (**C**) Ratio of F_λ values at the earth's surface for McMurdo for various dates and ozone amounts to those for Miami on 21 June: solid line, 5 October, 315 DU; dot-dash line, 5 October, 110 DU; and dashed line, 21 December, 350 DU.

Department of the Geophysical Sciences, University of Chicago, 5734 South Ellis Avenue, Chicago, IL 60637.

ratio (McMurdo to Miami) is 0.70 to 0.75. The ratio decreases rapidly toward shorter wavelengths as absorption by ozone becomes significant. The spectra of Fig. 1A serve as baselines against which to measure Antarctic radiation levels during periods of reduced ozone.

Irradiances computed for McMurdo with a solar zenith angle of 71.6°, appropriate to noon on 5 October, are shown in Fig. 1B. An ozone amount of 315 DU is typical of observations during October at Halley Bay, Antarctica, in years prior to 1968 (7). A column ozone of 250 DU existed over McMurdo in early September of 1987, whereas the lowest value observed anywhere over Antarctica was slightly below 110 DU on 5 October 1987 (*8*). At wavelengths greater than 340 nm, an ozone reduction has no impact on surface irradiances. However, at a wavelength of 315 nm, a decrease in ozone from 315 to 110 DU is accompanied by a factor of 2.2 increase in irradiance. At 305 nm the corresponding enhancement is a factor of 14.

Downward irradiances computed for McMurdo and normalized to results for Miami at summer solstice are shown in Fig. 1C. This comparison pertains to an assessment of human health during extended visits to Antarctica. Results appear for McMurdo on 5 October with ozone amounts of 110 and 315 DU and 21 December with 350 DU. All of the ratios in Fig. 1C are less than unity. However, the total radiation field includes both downward and upward components. The upward component over a snow-covered Antarctic surface makes a greater contribution to the total irradiance than is the case for Miami at summer solstice. Even with such adjustments, life forms accustomed to summer radiation levels at low to middle latitudes would not have experienced abnormally large UV-B exposure under conditions encountered in Antarctica through 1987.

The two curves in Fig. 1C for unperturbed ozone levels, 5 October with 315 DU and 21 December with 350 DU, show the expected decrease in irradiance toward short wavelengths relative to Miami. However, the curve for 110 DU on 5 October is nearly horizontal and illustrates the large irradiance increases that can occur at wavelengths where absorption by ozone is important. The noontime UV-B irradiance on 5 October with 110 DU of ozone exceeds that for Antarctic summer solstice at wavelengths shorter than 310 nm. Random fluctuations in ozone from day to day are small compared with the absolute changes that occur as the ozone hole develops and dissipates from September through November (7). The differences between curves in Fig. 1, B and C, arise from the elevation of the sun at local noon and the ozone amount. Systematic changes in irradiance over a time scale of 1 month exceed any random variations related to the daily behavior of ozone within the polar vortex.

Biological responses to UV radiation depend on the convolution over wavelength of solar radiation with an action spectrum, in which the action spectrum measures the relative sensitivity of an organism to damage by sunlight of varying wavelengths. We refer to this convolution as the biologically effective irradiance. The action spectrum for erythema (*9*), a reddening of the skin and the likely initial step in the development of some types of skin cancer, is shown in Fig. 1A. This action spectrum decreases by three orders of magnitude as wavelength increases from 295 to 340 nm.

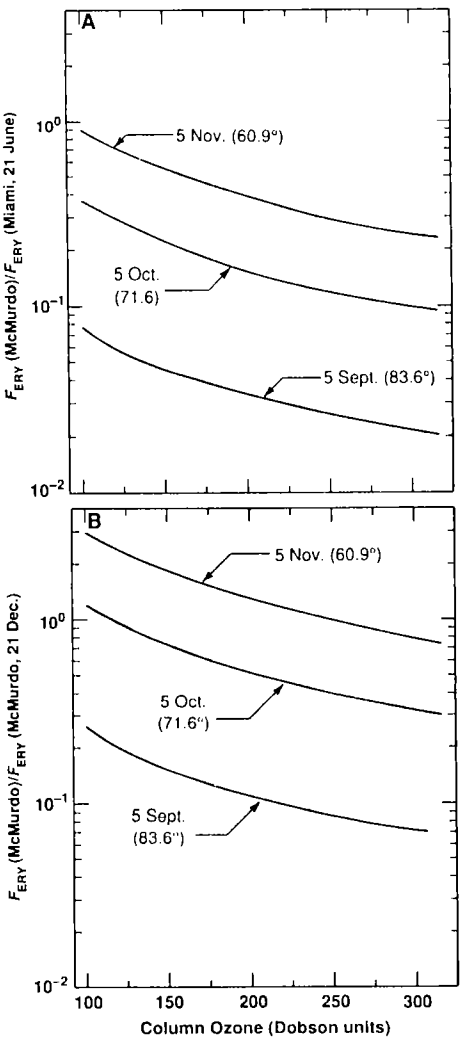


Fig. 2. Ratio of biologically effective downward irradiance (F_{ERY}) computed for a range of ozone values at McMurdo (**A**) to that for Miami on 21 June and (**B**) to that for McMurdo on 21 December. All values refer to local noon. The solar zenith angles for McMurdo appear in parentheses. The ozone amount at Miami is 280 DU and at McMurdo on 21 December is 350 DU.

The biologically effective downward irradiance computed for McMurdo, normalized to that for Miami on 21 June, is shown in Fig. 2A for a range of ozone values from 100 to 315 DU and solar zenith angles for local noon on 5 September, 5 October, and 5 November. As expected from Fig. 1C, all of the ratios remain less than unity for ozone values encountered through 1987. However, if the curves of Fig. 2A were adjusted to refer to total irradiance, the sum of downward and upward components, all of the ratios would be increased by a factor of 1.7. Based on this measure, a column ozone value of 140 to 145 DU over Antarctica on 5 November would imply a total biologically effective irradiance at noon equal to that at summer solstice at the latitude of Miami. An ozone column of 65 to 70 DU would provide the same noontime irradiance on 5 October. The latter values are less than any observed through 1987. In Fig. 2B the biologically effective irradiance for McMurdo is normalized to the 21 December value with an ozone column of 350 DU. During October and at least early November 1987, it is likely that the biologically effective irradiance at the earth's surface was near or exceeded values typical of an unperturbed Antarctic summer solstice.

One should also consider the biologically effective irradiance integrated over 24 hours. We computed integrated values appropriate to McMurdo for 5 October with 110 DU of ozone and 5 November assuming 150 DU, and took the ratio of these to the integrated irradiance for 21 December with 350 DU of ozone. These ratios are 0.75 to 0.80 for 5 October and 1.5 to 1.6 for 5 November. Note that the time of minimum ozone amount is not the time of maximum irradiance. From October through December, the solar zenith angle at a fixed local time decreases. This effect leads to an increase in surface irradiance even though ozone amounts are recovering toward unperturbed values after an October minimum. The magnitude of the radiation dose, integrated over an Antarctic spring, depends on details of the ozone depletion's temporal decay combined with the rising of the sun toward summer solstice. Any change in the recovery time of the ozone layer would be especially significant here. From the standpoint of Antarctic life, the ozone hole provides a greatly extended period of summerlike UV radiation levels, beginning in October. This phenomenon merits detailed study from the standpoint of photobiology and ecology.

REFERENCES AND NOTES

1. J. Calkins, *The Role of Solar Ultraviolet Radiation in Marine Ecosystems* (Plenum, New York, 1982); R. Worrest and M. Caldwell, *Stratospheric Ozone Reduc-*

tion, Solar Ultraviolet Radiation and Plant Life (Springer-Verlag, Berlin, 1986).
2. R. Stolarski *et al.*, *Nature* **322**, 808 (1986).
3. J. Calkins and T. Thordardottir, *ibid.* **283**, 563 (1980).
4. J. Frederick and D. Lubin, *J. Geophys. Res.* **93**, 3825 (1988).
5. *Atmospheric Ozone 1985, Assessment of Our Understanding of the Processes Controlling its Present Distribution and Change* (National Aeronautics and Space Administration, Washington, DC, 1986).
6. One Dobson unit is equal to an ozone column content of 2.69×10^{20} molecules per square meter of horizontal area extending from the ground to the top of the atmosphere.
7. J. Farman *et al.*, *Nature* **315**, 207 (1985).
8. A. J. Krueger, personal communication (1987); *Science* **239**, 146 (1988).
9. B. Diffey, *Photochem. Photobiol.* **46**, 55 (1987).
10. Supported by the National Aeronautics and Space Administration under grant NAGW-873. We thank F. Urbach for useful discussions.

15 March 1988; accepted 27 May 1988

PRIMARY PRODUCTION

The total primary production of marine organisms (mostly phytoplankton) is estimated at 30 - 40 billion metric tons per year. The total annual primary production of terrestial vegetation is about 110 billion metric tons. At the present time forests cover about 30% of land surfaces. So the production of marine phytoplankton is probably roughly comparable to that of forests. (These production estimates and the chart below are taken from a paper by Berrien Moore who testified before you at the first Committee hearing in July 1987.)

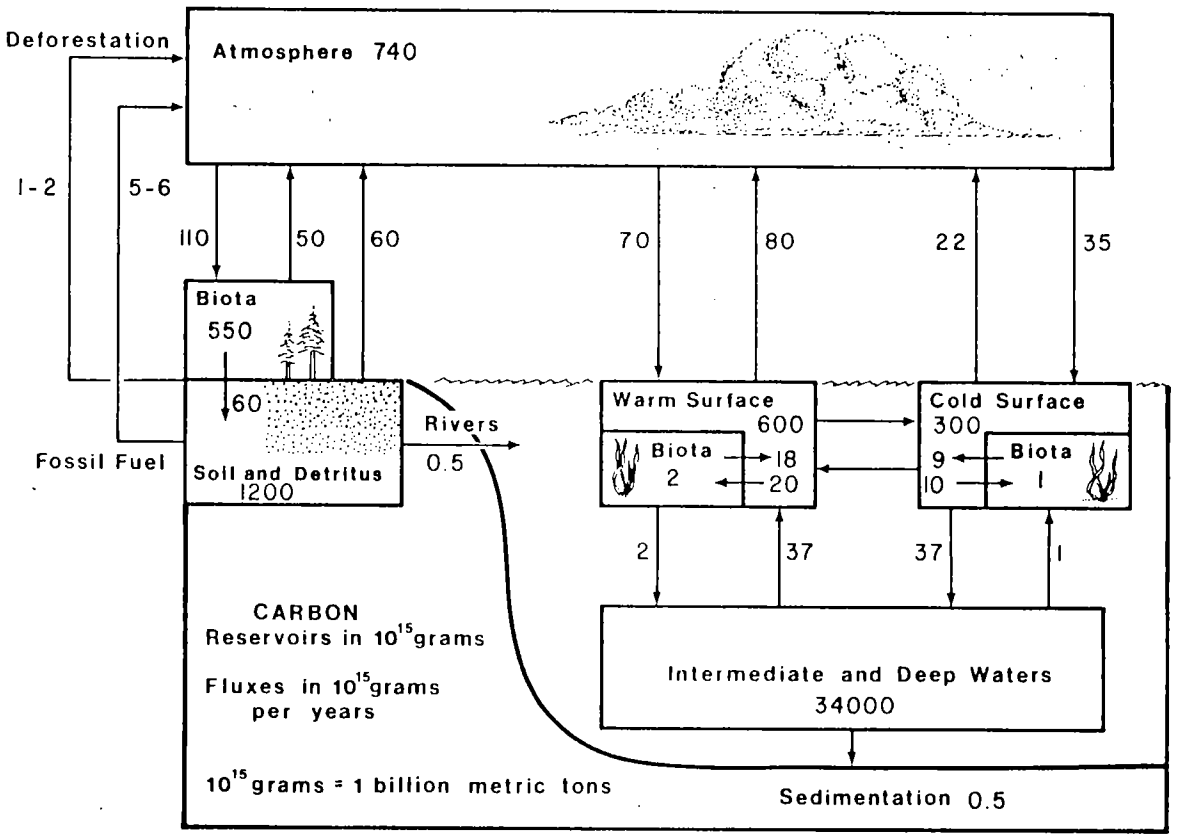


Figure 3. The global carbon cycle. Current estimates of the major reservoirs (in 10^{15} grams of carbon) and fluxes (in 10^{15} grams of carbon per year) involved in the global carbon cycle.

Rick

FYI

M. la Nelson

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

Subcommittee on Science, Technology, and Space

Witness List*

Hearing on

Arctic and Antarctic Ozone Depletion

Thursday, February 23, 1989, 9:30 a.m.

in Room SR-253 of the Russell Senate Office Building

Panel 1 - Scientists from the Arctic Ozone Expedition

Dr. Robert T. Watson, Earth Science and Applications Division, National Aeronautics and Space Administration, Washington, DC 20546

Dr. Adrian F. Tuck, Aeronomy Lab, National Oceanic and Atmospheric Administration, Boulder, CO 80303

Dr. Susan Solomon, Aeronomy Lab, National Oceanic and Atmospheric Administration, Boulder, CO 80303

Panel 2 - Manufacturers and Users of Chlorofluorocarbons

Dr. Joseph Glas, Director, Freon Products, E.I. DuPont, Inc., Wilmington, DE 19898

Ms. Marilyn I. Montgomery, Vice President and General Manager, Genetron Products, Allied-Signal, Inc., Morristown, NJ 07962

Mr. Arnold Braswell, President, Air Conditioning and Refrigeration Institute, Arlington, VA 22209

*Not necessarily in order of appearance

Thought you'd like one of these
Mike Nelson

WITNESSES FOR OZONE DEPLETION HEARING

February 23, 1989

First panel

Three of the team leaders of the Airborne Arctic Stratospheric Expedition:

change → Dr. Robert Watson from NASA, expedition co-leader
Dr. Adrian Tuck, NOAA atmospheric scientist, expedition co-leader
Dr. Susan Solomon, the NOAA scientist who organized the first Antarctic Ozone Hole expedition

In addition to discussing their work in the Arctic, the witnesses can provide an update on the Antarctic Ozone Hole and on research on global ozone layer depletion.

Second panel

Producers and users of CFCs

Dr. Joseph Glas, head of Dupont's Freon Division – Wilmington – Ph.D. chem.
Someone from Allied-Signal (hopefully, Mary Good, Chairman of NSF's National Science Board and Vice President for Technology at Allied-Signal)
Arnold Braswell, president of the Air Conditioning and Refrigeration Institute

Date. The hearing is scheduled for 9:30 on February 23.

GE — main compressor plant in TN

United States Senate

MEMORANDUM

Rick,

Al approved this at the hearing this morning.

Leon and Marla have copies.

Marla is working on material for a press release for tomorrow. Call me.

Mike

MEMORANDUM

FOR: SENATOR GORE
FROM: MIKE NELSON AND RICK ADCOCK
RE: PROPOSED FORMAT FOR OZONE DEPLETION HEARING

February 7, 1989

Arctic ozone research expedition. Since January 1, more than 100 researchers, including scientists from NASA, NOAA, and NSF, have been looking for evidence of stratospheric ozone depletion in the Arctic. During a similar expedition last year, researchers discovered a small version of the Ozone Hole over Greenland. Apparently, chlorofluorocarbons are causing ozone depletion over the Arctic as well as the Antarctic. Although the amount of depletion appears to be less than over Antarctica, the proximity to populated regions makes Arctic ozone depletion a greater concern.

Three of the team leaders for the Arctic ozone expedition have agreed to testify about their findings at a Science Subcommittee hearing on February 23, shortly after they return from Norway. This will be the first Congressional hearing focused on the Arctic Ozone Hole. Witnesses will include Dr. Robert Watson from NASA, Dr. Dan Albritton, head of NOAA's Aeronomy Lab, and Dr. Susan Solomon, the NOAA scientist who organized the first Antarctic Ozone Hole expedition. In addition to discussing their work in the Arctic, the witnesses can provide an update on the Antarctic Ozone Hole and on research on global ozone layer depletion.

Following the panel of researchers, we propose to have industry representatives discuss the progress that is being made in replacing CFCs and the hurdles that remain. Mary Good, Chairman of NSF's National Science Board and President for Engineered Materials Research at Allied-Signal, would be an excellent witness and is willing to testify. Dr. Joseph Glas from DuPont and Arnold Braswell, president of the Air Conditioning and Refrigeration Institute, can also testify. This would provide a chance to see where the Federal government could provide additional research funding to facilitate the development of alternatives to CFCs. It is also possible that changes in federal regulations and procurement procedures could cut CFC use. There is a lot of interest in this hearing among the research community, in industry, and among other members of the Subcommitttee (particularly Senator McCain).

Results. This hearing will publicize the research being done on the Arctic Ozone Hole. It provides an opportunity to reaffirm the link between chlorofluorocarbons and ozone layer depletion and to emphasize the need to cut production of ozone-depleting chemicals like CFC's. In addition, it will be a chance to highlight come very valuable work being done on CFC alternatives by the National Institute of Standards and Technology, which falls under the Subcommittee's jurisdiction. The hearing will also be a forum for promoting your global change bill.

Date. The hearing is scheduled for 9:30 on February 23. The hearing and the time have been cleared with Hollings, Danforth, and Pressler.

MEMORANDUM

FOR: SENATOR GORE
FROM: MIKE NELSON AND RICK ADCOCK
RE: PROPOSED FORMAT FOR OZONE DEPLETION HEARING

February 7, 1989

Arctic ozone research expedition. Since January 1, more than 100 researchers, including scientists from NASA, NOAA, and NSF, have been looking for evidence of stratospheric ozone depletion in the Arctic. During a similar expedition last year, researchers discovered a small version of the Ozone Hole over Greenland. Apparently, chlorofluorocarbons are causing ozone depletion over the Arctic as well as the Antarctic. Although the amount of depletion appears to be less than over Antarctica, the proximity to populated regions makes Arctic ozone depletion a greater concern.

Three of the team leaders for the Arctic ozone expedition have agreed to testify about their findings at a Science Subcommittee hearing on February 23, shortly after they return from Norway. This will be the first Congressional hearing focused on the Arctic Ozone Hole. Witnesses will include Dr. Robert Watson from NASA, Dr. Dan Albritton, head of NOAA's Aeronomy Lab, and Dr. Susan Solomon, the NOAA scientist who organized the first Antarctic Ozone Hole expedition. In addition to discussing their work in the Arctic, the witnesses can provide an update on the Antarctic Ozone Hole and on research on global ozone layer depletion.

Following the panel of researchers, we propose to have industry representatives discuss the progress that is being made in replacing CFCs and the hurdles that remain. Mary Good, Chairman of NSF's National Science Board and President for Engineered Materials Research at Allied-Signal, would be an excellent witness and is willing to testify. Dr. Joseph Glas from DuPont and Arnold Braswell, president of the Air Conditioning and Refrigeration Institute, can also testify. This would provide a chance to see where the Federal government could provide additional research funding to facilitate the development of alternatives to CFCs. It is also possible that changes in federal regulations and procurement procedures could cut CFC use. There is a lot of interest in this hearing among the research community, in industry, and among other members of the Subcommitttee (particularly Senator McCain).

Results. This hearing will publicize the research being done on the Arctic Ozone Hole. It provides an opportunity to reaffirm the link between chlorofluorocarbons and ozone layer depletion and to emphasize the need to cut production of ozone-depleting chemicals like CFC's. In addition, it will be a chance to highlight come very valuable work being done on CFC alternatives by the National Institute of Standards and Technology, which falls under the Subcommittee's jurisdiction. The hearing will also be a forum for promoting your global change bill.

Date. The hearing is scheduled for 9:30 on February 23. The hearing and the time have been cleared with Hollings, Danforth, and Pressler.

MEMORANDUM

FOR: SENATOR GORE

FROM: MIKE NELSON

RE: HEARING ON ARCTIC AND ANTARCTIC OZONE DEPLETION

February 7, 1989

Arctic ozone research expedition. Since January 1, more than 100 researchers, including scientists from NASA, NOAA, and NSF, have been looking for evidence of stratospheric ozone depletion in the Arctic. During a similar expedition last year, researchers discovered a small version of the Ozone Hole over Greenland. Apparently, chlorofluorocarbons are causing ozone depletion over the Arctic as well as the Antarctic. Although the amount of depletion appears to be less than over Antarctica, the proximity to populated regions makes Arctic ozone depletion a greater concern.

At 9:30 on February 17, soon after they return from Norway, the research team will hold a news conference to discuss their findings. They have agreed to testify about their findings at a February 23 Science Subcommittee hearing, which will be the first Congressional hearing focused on the Arctic Ozone Hole. (There are two House hearings on global change scheduled for February 21 where the results from the Arctic will probably be mentioned.) Witnesses will include Dr. Robert Watson from NASA, Dr. Dan Albritton, head of NOAA's Aeronomy Lab, and Susan Solomon, the NOAA scientist who organized the first Antarctic Ozone Hole expedition.

In addition to discussing their work in the Arctic, the witnesses can provide an update on the Antarctic Ozone Hole and on research on global ozone layer depletion.

Following the panel of researchers, it would be useful to have industry representatives discuss the progress that is being made in replacing CFCs and the hurdles that remain. Mary Good, Chairman of NSF's National Science Board and President for Engineered Materials Research at Allied-Signal, is eager to testify. This would provide a chance to see where the Federal government could provide additional research funding to facilitate the development of alternatives to CFCs. It is also possible that changes in federal regulations and procurement procedures could cut CFC use. Senator McCain has been very interested in cutting production of CFCs, in part because of the very high skin cancer rate in Arizona, and would appreciate a chance to highlight the need for CFC cuts.

Don't know

Results. This hearing will publicize the research being done on the Arctic Ozone Hole. In addition, it provides an opportunity to reaffirm the link between chlorofluorocarbons and ozone layer depletion and to emphasize the need to cut production of ozone-depleting chemicals like CFC's. The hearing will also be a forum for promoting your global change bill.

Date. The hearing is tentatively scheduled for 9:30 on February 23. The hearing and the time have been cleared with Hollings, Danforth, and Pressler.

Rick, This part may change (of course)

Do you want your name on this memo?

Mike Nelson

Combo news conference / hrg is out —

All will be involved in US press conf.

(Studies diff species) Norway – England – US

NOAA Aeronomy lab — Hrg. the afternoon of the 17th

Dr. Albritton/NOAA → no members or Bob Nelson

Susan Solomon/NOAA → for good press

Adrian Tuck/NOAA → not cleared by Hollings or minority

Hrg on the 23rd

→ Bob Watson

Mary Good

→ Allied Chem, VP Research

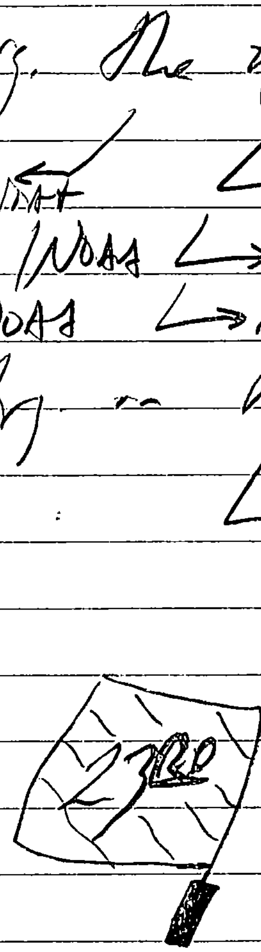
→ NSF ~~[illegible]~~ Nat'l Science Board — Head of [illegible] NSF's Board of Directors

Allied & DuPont making important decisions

→ plus more members (incl. McCain — a good ally)

Allied

DuPont



Arctic is one piece of the puzzle

* Bob Corell / NSF

↳ what scientists are telling us
+ what Fed agencies are doing

2/23 CFCs / Ant Ar O_3 | trying their press release until 2/23 ↓ tomorrow find out

(O_3 Hole, Arc expedition, Arctic Survey team)

* Early March (Mar 14) "Surprises"

— Woodwell — W. Antarctic ice sheet slip off
— Broecker — CH_4 from permafrost?

#

EPA Report on ↑ UV impacts

* McCain Bill to recycle CFCs — Feds buy 1/3 of CFCs in the country

↳ (R-AZ) — -

2/27
3/2
3/7
} NASA Budget Hrgs — some w/ global change components

→ USA Today → Q+A

∴ 11-12 hearings on the next 4 weeks

Notebook for Each Hearing

Hy memo
Short summary for each witness
Articles from papers + trade pubs on subject
CRS materials
Visual graphic material

AA to participate in design of hearing

AA quotes into Hdlrs/Subcomm. press releases
& simultaneous release from AA's office

Any interview of Mzlr on hearing
announced

For AA — Opening statements
Questions for witnesses

For approval / edits

FOR IMMEDIATE RELEASE
FRIDAY, FEBRUARY 17, 1989

CONTACT: Marla Romash
202-224-4944
202-547-0806 (H)

GORE CITES SCIENTISTS' REPORT, CALLS FOR TOUGHER OZONE PROTECTIONS
Says Recent Findings Illustrate Urgent Need for Int'l Action

WASHINGTON-- The just-released findings of an international team of scientists -- confirming the threat of man-made chemicals to the earth's protective ozone shield -- reinforce the need for U.S. legislation to phase-out those chemicals here, and changes to an international agreement to speed up their ban around the globe, said U. S. Sen. Al Gore, D-TN, who next month will travel to London as part of the U.S. delegation to an international conference on ozone protection.

"This report should and must act as an international catalyst to spark new discussions and more comprehensive action," Gore said. "The scientists are telling us that what they first suspected from laboratory blackboards is in fact happening in the real world. These chemicals are creating serious problems with long-term environmental consequences for every person on the planet."

Gore is the author of the World Environment Policy Act of 1989, among the most comprehensive environmental protection proposals of this Congress, which confronts the broad array of culprits responsible for global pollution, including the destruction of the earth's protective ozone shield.

Gore's bill, for example, calls for a phased-in ban of chloroflourocarbons, the chemicals scientists have found to be responsible for the destruction of the stratospheric ozone.

"There is a clear need for Congressional action and recognition that the scientists findings must be translated into policies that will stop this devastation," Gore said. "We are facing the most vital environmental challenge of our lifetimes, of any time, and we cannot afford to hesitate or falter."

One of

"We have the opportunity next month, in London, to begin the international discussions which will allow us to move beyond the Montreal Protocol to even more meaningful protections, " Gore said. "It is my hope that the seeds we plant in March, will bear fruit in April when those nations who are parties to that protocol meet in Finland."

"Representatives of ~~the~~ about 100 nations who will participate in London will have the opportunity to take back to their governments the need for strict new controls on CFCs, for a much faster timetable on the chemicals' ban than that provided for in the Montreal Protocol," Gore said. "We know much more now than we did when ~~that~~ the protocol was negotiated. It's time our policies reflected the urgency that our scientists have so clearly demonstrated."

##

ADDITIONAL QUESTIONS FOR ARCTIC OZONE EXPEDITION PANEL

The old models underestimate how serious ozone depletion is

1. I have some plots which predict how ozone depletion will increase in the future under different scenarios. This figure is from a 1987 EPA "Assessment of the Risks of Stratospheric Modification". According to EPA models, if we rolled back worldwide CFC emissions to 1980 levels (that's about 10% less than today), there would be about a 3% depletion of the ozone layer at higher latitudes.

   The EPA models don't take into account the accelerated ozone depletion that is you have documented in the polar regions. It seems to me that your research indicates that these models are overly optimistic because they grossly underestimate the problem.

   - Just how much worse is the problem?

   I also have a figure from a more recent EPA report on "Future Concentrations of Stratospheric Chlorine and Bromine". This one shows how chlorine concentrations will rise in the future according to different scenarios. It shows two curves, with huge errors bars, the lower one is for a 100% worldwide phaseout of CFCs and the upper one is for a phaseout with 92% compliance. This graph doesn't predict ozone depletion, just the concentration of the chlorine that causes it.

   According to this figure, even if we got 92% worldwide compliance with a total CFC ban, we'd still get twice the current levels of chlorine by the year 2000 and 4 times current levels by 2050.

   Even with a total CFC phaseout, represented by this lower curve, chlorine concentrations will go up 50% by the year 2000 and they'll stay high for decades.

   - Is this figure more reliable than the first one?

   - What do these curves translate into in terms of ozone depletion?

Need to separate the science from the policy

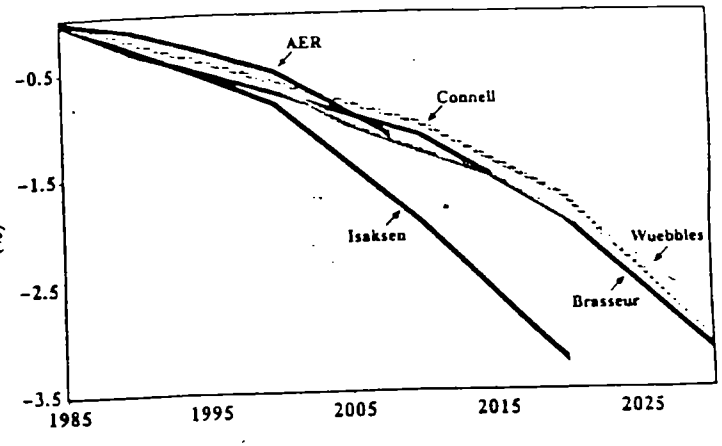
2. I noticed that the Arctic Ozone Expedition did not receive funding from EPA, the agency responsible for regulating CFC production.

   - Why is that?

   - In general, how important is it that the science be independent of policy?

EXHIBIT 10

Model Comparison for Coupled Scenario: 1-D and 2-D Model, Global Average



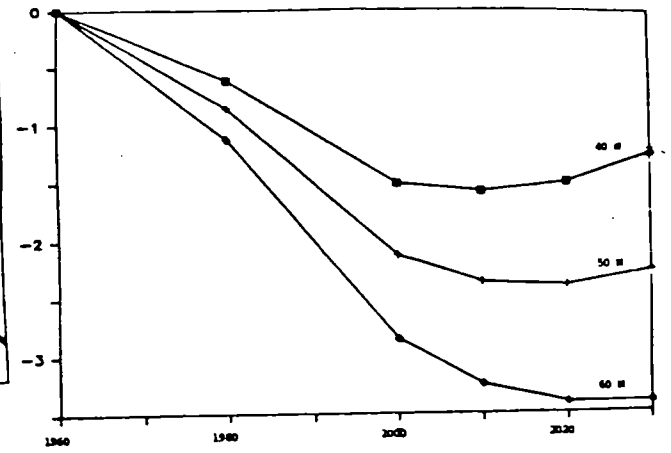
Global average change in total column ozone as calculated by several modeling groups for a common scenario of:

Compound	Growth Rate (% per year)
CFCs	3.0 (emissions)
CH4	1.0 (concentrations)
N2O	0.25 (concentrations)
CO2	-0.60 (concentrations)

Results shown for 2-D models of Isaksen and AER, 1-D models of Brasseur and Wuebbles, and Connell's parameterization of the LLNL 1-D model.

Source: Chemical Manufacturers Association, (1986); World Meterorological Organization, (1986); Connel, (1986); Brasseur and DeRudder, (1986); and Isaksen and Stordal, (1986).

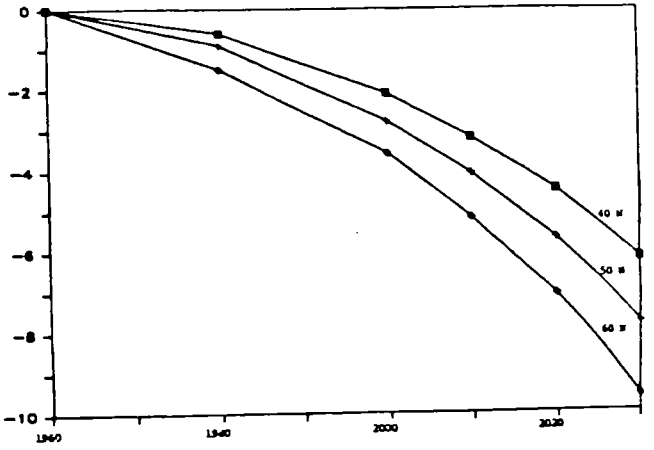
Two Dimensional Model: CFC Emissions Rolled Back to 1980 Levels



Results shown from constant CFC emissions at the 1980 level (approximately 10% less than current emissions for time dependent seasonally-averaged change in ozone for 1980 CFC emissions and coupled perturbations); CH4 concentrations at 1% per year, N2O concentrations at 0.25% per year, and CO2 concentrations at approximately 0.5% per year. Changes shown for 40°N, 50°N, and 60°N. Temperature feedback considered in model.

Source: Isaksen (personal communication).

Depletion by Latitude for 3% Growth CFCs



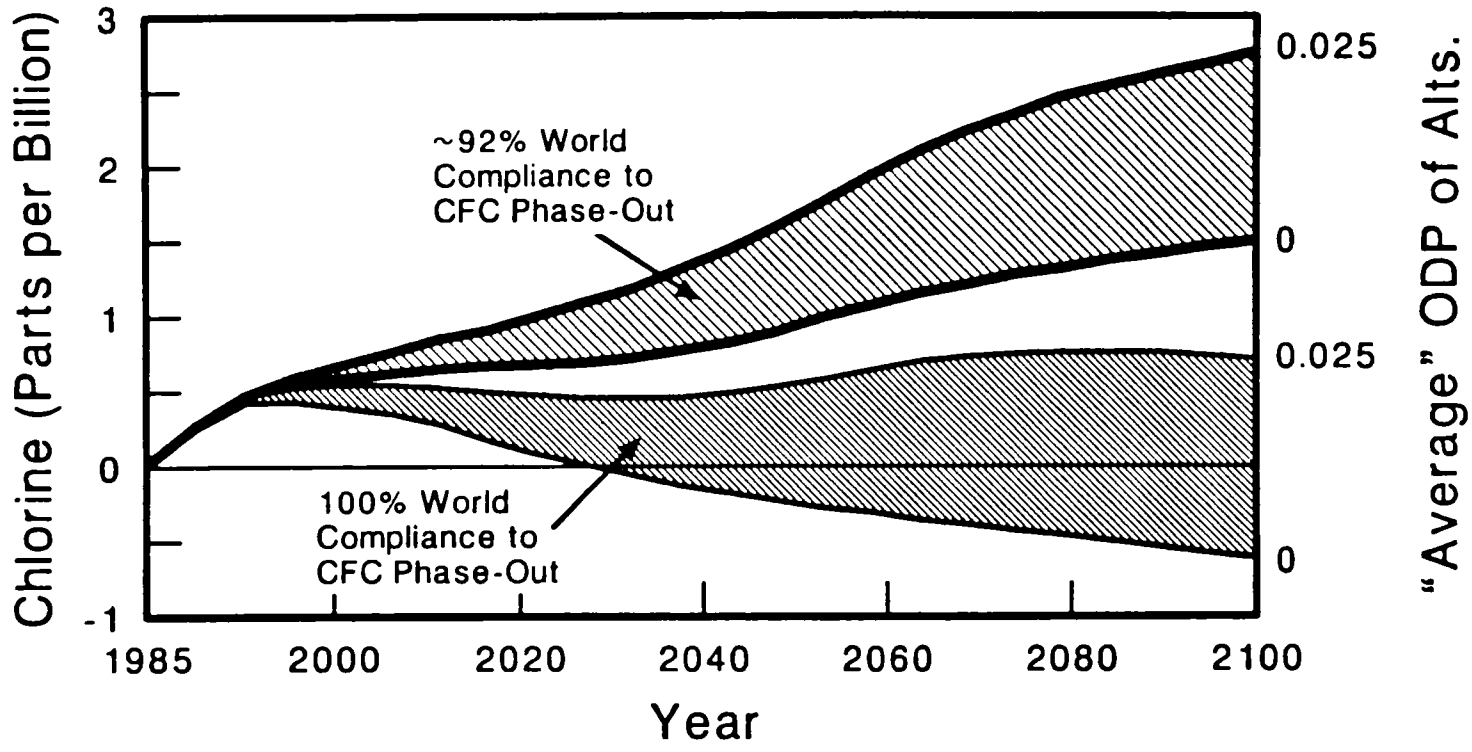
Results shown for time dependent seasonally-average changes in ozone for 3% growth per year in CFC emissions; 1% growth in CH4 concentrations; 0.25% growth in N2O concentrations, and approximately 0.5% growth in CO2 concentrations. Changes shown for 40°N, 50°N, and 60°N. Temperature feedba considered in model.

Source: Isaksen (personal communication).

1987 EPA report

Importance of Alternatives

Calculated Change in Stratospheric Chlorine



Base Assumption: 2.8%/ Yr Growth 1985-2050

Source: Data from Exhibit 23, p. 51 of "Future Concentrations of Stratospheric Chlorine and Bromine," EPA Report 400/ 1-88/ 005 by J. S. Hoffman and M. J. Gibbs.

PRIMARY PRODUCTION

The total primary production of marine organisms (mostly phytoplankton) is estimated at 30 - 40 billion metric tons per year. The total annual primary production of terrestial vegetation is about 110 billion metric tons. At the present time forests cover about 30% of land surfaces. So the production of marine phytoplankton is probably roughly comparable to that of forests. (These production estimates and the chart below are taken from a paper by Berrien Moore who testified before you at the first Committee hearing in July 1987.)

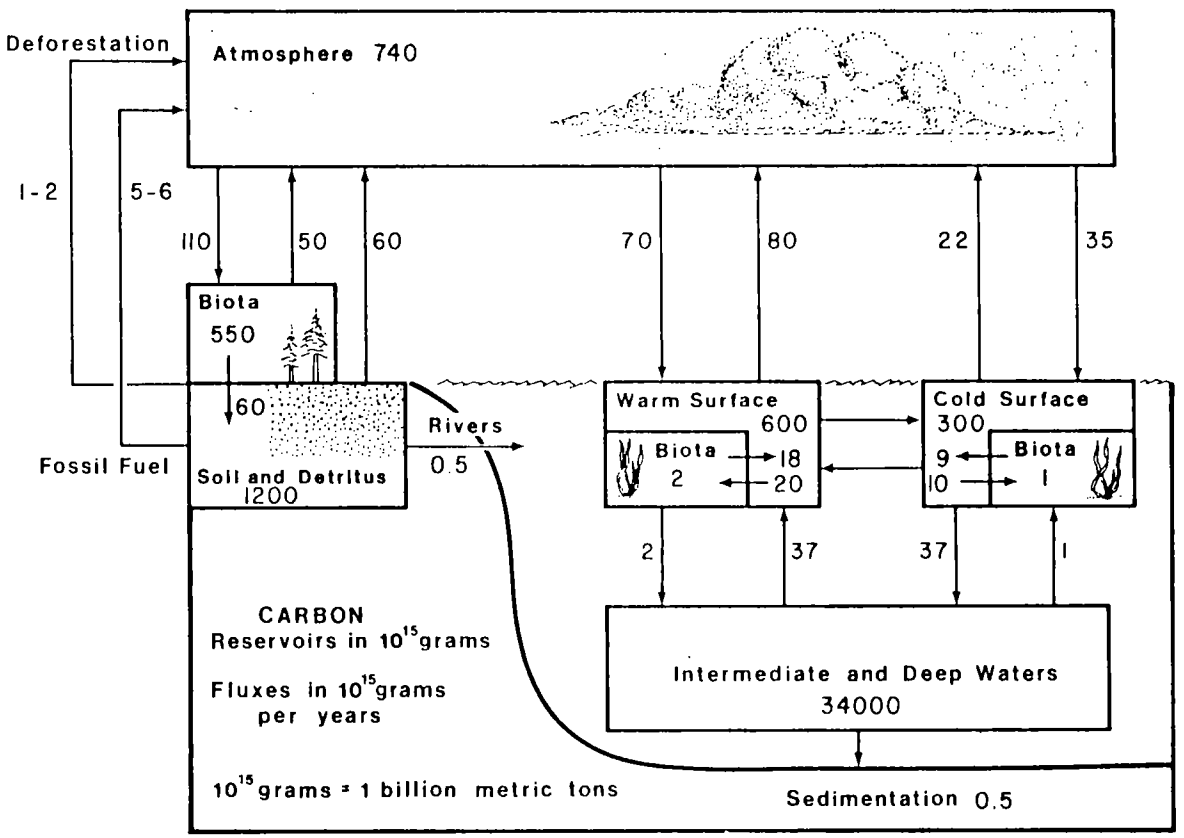


Figure 3. The global carbon cycle. Current estimates of the major reservoirs (in 10^{15} grams of carbon) and fluxes (in 10^{15} grams of carbon per year) involved in the global carbon cycle.

M E M O R A N D U M

DATE: February 23, 1989

TO: Al

FROM: Rick

SUBJECT: Strategy for Today's Hearing

Key themes and strategy to pursue at the CFC-Ozone Hearing today:

PANEL 1

(a) Aim all policy-type questions first at Watson, second at Solomon, and never (if possible) at Tuck.

(b) Do not ask them questions that refer to a specified phaseout period; keep it qualitative always. For example, do not ask them if we should phase out all CFCs in a five-year period. Rather, ask them whether they feel that their science has revealed problems in the upper atmosphere that warrent an "urgent" response on our part.

(c) Do not let the idea of "uncertainty" be read as meaning that things may not be as bad as they sound -- uncertainty should NOT be taken by the public as an excuse for complacency. When the scientists on the panel today speak of uncertainty, they mean uncertainty in BOTH directions: things may not be so bad, but things may also be a lot worse than we realize.

Along these lines, you might ask WATSON: Scientists, in their search for precise understanding of phenomena, often speak of uncertainties. Here today, you have referred to the uncertainties regarding the actions and interactions of these chemicals in the atmosphere. But I want to understand one point very clearly: when you speak of uncertainty, you do not mean to convey the message that things may not be as bad as your results suggest; indeed, things may be a lot worse, and we may be in for some rude surprises in the future if we do not deal with this problem effectively. Is that a correct interpretation of what you mean when you say that there are "uncertainties"?

PANEL 2

(a) After receiving the testimony from the industry representatives, tell them something along these lines:

Gentlemen, I'm not here to challenge you as to which substitutes are commercially ready, which are promising, and which are proving to not be a solution. Only you can provide that information, because it is from your own research and development that you can draw those conclusions.

Gentlemen, this is the Commerce Committee. I specifically directed that, in this first hearing, we have representatives from the industrial perspective -- unchallenged by witnesses from places like public interest groups, or the EPA. I want you to present your best estimates of where U.S. industry is in addressing this GLOBAL problem.

In coming weeks, I will hold a second hearing on this subject, featuring witnesses who will discuss the imnpacts of stratospheric ozone depletion on human health, on agricultural crops, on the aquatic organisms that form the basis of all life in the oceans -- oceans on which human life as we know it depend.

(Ad lib here that their threats of a disruption in life as we know that MIGHT result if we phase-out CFCs tomorrow are NOTHING compared to the disruptions that will occur if crops fail and ocean life is diminished and we cannot go outside without Secretary Hodel's sunscreen and floppy hats.)

In coming weeks, I will also travel to London for an international conference sponsored by Mrs. Thatcher. There, I will hear about the efforts of European and Japanese industries in the search for alternatives. Gentlemen, this is a not only a question of halting the destruction of the world's atmosphere and disruption of the world's climate... and preventing the social disruption that would certainly result. For you gentlemen, it is a question of competitiveness. The world is awaiting a solution, and I am certain that the creativeness of the U.S. industry is up to the challenge.

But I do want to talk here now about some things that we should be doing, actions that we can take that do not depend on when and where substitutes are found.

GO TO LAST NIGHT'S MEMO...RECYCLING, ETC.

M E M O R A N D U M

DATE: February 22, 1989

TO: Al

FROM: Rick

SUBJECT: Thoughts on Tomorrow's Hearing

I think that we need to proceed with a great deal of care tomorrow, to avoid letting the second panel leave the impression that there is nothing that we can do about phasing out CFCs in the period of time called for in S.201.

The sand that the industry will throw in your face will probably proceed along lines similar to the following:

(1) We need time to do toxicology tests -- we don't want to replace one dangerous pollutant with another. (They say that this takes three to five years.)

(2) We can only begin to build new plants once we have completed tox testing. At that point, it will take X years to begin porducing the new substitutes in large quantities. (They'll probably claim that this will take about 1 year -- on top of the three-to-five.)

(3) We need time to replace all of the old equipment that relied on CFCs with new equipment that is designed to use the new fluids. Two principal complaints here: (a) the oil in the old equipment cannot be allowed to mix with the new CFC substitute, because that will degrade the substitute's performance (oils and CFC's are matched to work together); and (b) the equipment is designed around the properties of the working fluid (CFCs), and so may not operate properly with a substitute fluid.

It is difficult to argue these points because, in the end, only the industry has the expertise to answer questions about the timing of introducing substitutes. And, after listening patiently to what will certainly be a round of "we just can't do it any faster...the EPA requires these tox tests, etc.", you could make that point to them: They have been asked to testify in order to provide their best answers to these questions of timing.

THEN, nail them with the following:

What are you doing NOW to improve the management of the chemicals that are out there, in terms of improved recapture and recycling of CFCs? Specifically:

(1) Are you working with auto makers to make air conditioning systems more servicable and less prone to leakage? For instance, why don't you work with the auto makers to improve the quality hoses and fittings to reduce leakage? Shouldn't we be using aircraft-quality hoses and fittings?

(2) Along these same lines, are you working with the refrigeration industry to make design changes that allow more efficient recapture and recycling of CFCs? And is that industry training its service representatives to recycle CFCs every time that they repair a refrigerator, or any other CFC-containing equipment? (Point this one at Braswell).

(3) Are you working with insurance companies to develop fire-extinguisher testing alternatives to the full-flood testing (on computer centers, communications centers, etc.) that unnecessarily releases vast amounts of halons to the atmosphere during every single test using current procedures?

Items (1), (2) and (3) are no- to low-cost options that DO NOT reduce the utility of the existing chemicals, but DO reduce their damage to the environment.

(4) VERY IMPORTANT -- What commitments have you made to prevent the construction of manufacturing plants in the developing world that either produce harmful CFCs, or the equipment that relies on them? Is you company engaged at this time in any joint overseas ventures that involve production of the chemicals addressed by the Montreal Protocol...or in the manufacture of equipment that relies on these chemicals?

What commitments will you make in the next few years to stimulate overseas production of substitute chemicals, and equipment that relies on substitutes, especially in the developing world?

Finally, in order to prevent panel #2 from feeling that they're having the last word on this issue, I propose that we announce a follow-up hearing to tomorrow's hearing. The follow-up to be composed of two panels:

Panel #1: Impacts of Ozone Depletion -- discussing impacts on human health, agricultural crops, and aquatic systems; in

addition, a discussion of the interactions and synergy among stratospheric ozone depletion, the greenhouse effect, acid rain, and urban air pollution.

Panel #2: Policy Responses to Build International Cooperation and Reduce the Risks of Ozone Depletion -- including discussion of current and planned responses in the Western countries, the East Bloc, and the developing world.

Ok?

MEMORANDUM
February 17, 1989

TO: DEMOCRATIC MEMBERS, SENATE COMMERCE COMMITTEE
FROM: MIKE NELSON AND PENNY DALTON
RE: FEBRUARY 23 HEARING ON ARCTIC AND ANTARCTIC OZONE DEPLETION

On Thursday, February 23, 1989, the Science, Technology, and Space Subcommittee will hold an oversight hearing on the depletion of the stratospheric ozone layer by chlorofluorocarbons (CFCs) and other man-made chemicals. The hearing will be held at 9:30 a.m. in Room 253 of the Russell Building. Senator Albert Gore, Jr., will chair the hearing.

The subcommittee will be briefed by the scientists who led a recently-completed research expedition to look for an Arctic ozone hole. Their findings indicate that the same chemicals that are responsible for the dramatic depletion of stratospheric ozone in the Antarctic ozone hole are also present over the Arctic. Thus, there is the potential for major depletion of ozone in the Arctic. Just a few percent depletion of the ozone layer would lead to increased ultraviolet (UV) radiation which could cause millions of additional cases of skin cancer and cataracts in the decades ahead. In addition, the increased UV radiation could cause serious damage to crops, forests, and marine ecosystems. Changes in the composition of the stratosphere can also lead to changes in stratospheric temperatures and global climate.

A second panel, consisting of representatives of companies which manufacture and use CFCs, will discuss the progress that has been made in finding replacements for CFCs and the problems which remain.

BACKGROUND

In 1974, Dr. Sherwood Rowland and Dr. Mario Molina, two chemists at the University of California, first pointed out that CFCs could cause depletion of the stratospheric ozone layer which shields the earth from harmful UV radiation. They found that CFCs are very stable and last for decades in the atmosphere. However, when they reach the stratosphere, 10 to 20 miles above the earth, UV radiation causes the CFC molecules to break apart, releasing chlorine, which in turn causes depletion of the ozone layer. A single atom of chlorine can destroy 100,000 molecules of ozone. Using simple chemical models, Rowland and Molina predicted that at current rates of CFC emissions, measurable amounts of ozone layer depletion would become apparent some time in the next century.

Impact of Ozone Depletion. The impact of increased UV radiation due to ozone depletion has not been adequately studied. There is scientific consensus that a few percent depletion of the ozone layer would lead to millions of additional cases of skin cancers and cataracts each year worldwide. In the United States this could mean thousands of additional deaths annually. Another concern is evidence that enhanced UV radiation could cause major damage to marine ecosystems. Some species of the tiny plankton that form the base of the marine food chain appear to be particularly sensitive to UV radiation. Changes in plankton productivity could decrease harvests of fish worldwide. Enhanced UV radiation can also decrease yields of several major crops.

Uses of CFCs. The three most important CFCs are: CFC-11, which is used in large air conditioning and refrigeration systems and in the manufacture of plastics and foam; CFC-12, which is used in household and automobile air conditioners; and CFC-113, which is used to clean computer chips. In the past, CFCs were used as a propellent in aerosol spray cans. In response to Rowland and Molina's theory, the United States banned the use of CFCs in aerosol cans in the mid-1970s. This led to a nearly 50% reduction in the use of CFCs in the United States. Unfortunately, other countries did not follow the U.S. lead and world CFC production levels are now at their highest level ever.

By the mid-1980s, scientific research confirmed that CFCs do pose a threat to the ozone layer. However, because ozone concentrations in the ozone layer vary naturally by 5-10% from year to year, there was no clear evidence that ozone depletion was occurring.

Discovery of the Antarctic "Ozone Hole". In 1985, British scientists in Antarctica reported that stratospheric ozone concentrations during the spring over Antarctica had dropped by more than 40%. This dramatic reduction had not been predicted by Rowland and Molina's theory and led to a flurry of research activity. Analysis of data from a NASA satellite confirmed the existence of the Antarctic ozone hole. In 1986 and 1987, the National Ozone Expeditions, led by Dr. Susan Solomon discovered that CFCs were responsible for the ozone hole. Researchers found that ice crystals in polar stratospheric clouds caused complicated "heterogenous" chemical reactions which are much more effective at destroying the ozone layer than the simple chemical reactions modelled by Rowland and Molina. The ice in the clouds serves as a catalyst for speeding up the destruction of ozone by CFCs. Fortunately, these clouds can only form during the long polar nights at temperatures colder than -77 degrees Celsius. The ozone depletion process also requires sunlight. Thus, rapid ozone depletion does not begin until the sun returns to Antarctica in the spring, triggering the dramatic formation of the ozone hole.

Montreal Protocol. By 1985, the scientific evidence was compelling enough to convince the major CFC-producing nations to agree, in the Vienna Convention, to the need for global controls

on CFC production. The Montreal Protocol followed in September, 1987, and was ratified by most of the 24 signatory nations by the end of 1988. The Protocol requires that, beginning in mid-1989, developed countries freeze their CFC production and consumption at 1986 levels and cut production by 50% over the next 10 years. Production of halons, another family of ozone-depleting compounds which are used in fire extinguishers, is frozen at 1986 levels. Developing countries are given a ten-year delay in implementing production controls. They are free to increase CFC production until 1996.

Arctic Ozone Expedition. Last winter, scientists working in Norway, Greenland, and the Canadian Arctic, detected ozone-depleting chemicals in the stratosphere similar to those found in the Antarctic ozone hole. To investigate the possibility of an Arctic ozone hole, more than 100 researchers organized the international Airborne Arctic Stratospheric Expedition which started early in January, 1989. U.S. researchers from the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the National Science Foundation (NSF) were involved. In addition, scientists from the United Kingdom, Canada, Norway, and several other countries took part.

Using U-2 aircraft, a modified DC-8 airplane, balloon observations, and ground observations, researchers found many of the same ozone-depleting chemicals in the Arctic stratosphere that are present in the Antarctic ozone hole. However, thus far, no extensive ozone depletion has been detected. During the next two months, as spring approaches and sunlight returns, it is possible that an Arctic ozone hole will form. Researchers will continue their monitoring to see if it does.

Global Ozone Depletion. Ozone depletion at the poles is contributing to a worldwide decrease in ozone concentrations. In addition, ozone depletion is occurring at lower latitudes, albeit at a slower rate. Last March, the international Ozone Trends Panel, chaired by Dr. Robert Watson of NASA, reported that since 1969 there has been a 2-3% depletion of the ozone layer over the United States. During the winter months, ozone concentrations were 2-6% lower. These measurements indicated that ozone depletion was occurring 2-3 times faster than previously recognized. This is thought to be due in part to unexpected ozone depletion over the Arctic and Antarctic.

Calls for additional cuts in CFC production. The unexpectedly high rates of ozone depletion have led to calls for cuts in CFC production that are larger and faster than those stipulated in the Montreal Protocol. Last Congress, Senators Baucus and Chafee introduced S. 570 and S. 571, calling for cutting production of ozone-depleting CFCs and halons to 5% of 1986 levels by 1995. The bills also called for penalties for use of CFCs. In addition, Senator McCain introduced S. 2502, a bill to establish a task force charged with reducing federal government use of CFCs.

This year, Senator Gore introduced S. 201 which, along with other provisions, includes a call for a total ban on the production of the five most important ozone-depleting CFCs and halons by 1996. Three other ozone-depleting compounds would be banned by 2000. Senator Leahy has similar provisions in his S. 333. Both bills were referred to the Committee on Environment and Public Works.

The producers and users of CFCs are opposed to these rapid proposed cuts. They argue that a unilateral phase-out by the U.S. will put American industry at a competitive disadvantage vis-a-vis foreign companies. They also argue that it will take at least ten years to develop alternatives to CFCs, test their toxicity, build new production capacity, and adapt existing air-conditioning and refrigeration equipment to the new alternatives. Dupont and other companies have announced new compounds which can replace CFCs in some applications. Many of these new products consist of hydrofluorocarbons (HFCs) or mixtures of two or three liquids, sometimes including a small percentage of CFCs. Some industries, most notably the plastic and foam-blowing industries, have already taken steps to phase-out the use of CFCs. This will be more difficult in the refrigeration and air-conditioning sector.

POLICY QUESTIONS

What does the science tell us? The Arctic ozone expedition is providing more information about how ozone depletion occurs in the stratosphere. It is clear that CFCs are causing ozone depletion. However, there is still quite a bit of uncertainty about how fast ozone depletion will occur in the future.

Is the present research effort adequate? Will the present research effort provide the answers policy-makers need to make decisions on phasing out CFCs and other ozone-depleting substances? Research is needed not only on CFCs but also on halons and other compounds which destroy ozone. CFCs and halons are present in only a few parts per billion in the atmosphere and yet are causing worldwide environmental concerns. Are there other gases in the atmosphere about which we need to worry? The chemical companies are particularly concerned that they will develop CFC alternatives which will be found to be even worse for the environment than the CFCs they replace.

Is the federal research effort well-coordinated and well-planned? The Arctic and Antarctic ozone expeditions are good examples of how NOAA, NASA, and NSF can work together on global change research. Are these expeditions the rule or the exception? In January, Senator Hollings introduced S. 169, the National Global Change Research Act, to ensure such interagency cooperation.

Can federal research and development programs assist in the transition to CFC alternatives? Several million dollars are spent each year by the National Institute of Standards and Technology

(NIST, formerly the National Bureau of Standards), the Department of Energy (DOE), and the Environmental Protection Agency (EPA) for R&D on CFC alternatives and on refrigeration and air-conditioning equipment which uses them. Last year, Senators Hollings, Rudman, and McCain worked together to get an addition $250,000 appropriated for research on CFC alternatives at NIST. Has this effort been of use to CFC manufacturers and users? Should it be expanded?

How quickly can CFC production be phased down? What will the cuts required by the Montreal Protocol mean to industry? What would be the impact of an accelerated phase-out? In addition to regulating production of CFCs, several proposed bills call for fees for CFC use. The EPA is considering auctioning off CFC production rights. Predictably, CFC manufacturers and users oppose such proposals.

WITNESSES

The first panel of witnesses will consist of researchers from the Airborne Arctic Stratospheric Expedition. **Dr. Robert Watson** is head of NASA's Upper Atmosphere Research and Tropospheric Chemistry Branch. He was program scientist for the Arctic expedition and has been very involved in research on the Antarctic ozone hole. **Dr. Adrian Tuck**, co-leader of the expedition, is an atmospheric chemist from NOAA's Aeronomy Laboratory in Boulder. **Dr. Susan Solomon** is also from NOAA's Aeronomy Lab. She led the National Ozone Expeditions to the Antarctic which determined the cause of the Antarctic ozone hole. She was also part of the Arctic expedition. The panel will review the findings of the Arctic expedition, discuss the most recent findings from the Antarctic, and provide an update on research on global ozone depletion.

The second panel of witnesses consists of **Dr. Joseph Glas**, Director of Dupont's Freon Division, and **Robert Traflet**, President, Fluorine Products at Allied-Signal. Dupont and Allied-Signal are two of the largest producers of CFCs and are spending tens of millions of dollars developing alternatives to CFCs. In addition, **Arnold Braswell**, President of the Air-conditioning and Refrigeration Institute (ARI), will represent manufacturers of large air-conditioners and chillers for buildings and commercial refrigeration units. He will discuss the efforts that ARI members are making to replace CFCs in their equipment. Several other industry user groups have asked to submit testimony for the record.

FOR IMMEDIATE RELEASE
FRIDAY, FEBRUARY 17, 1989

CONTACT: Marla Romash
202-224-4944
202-547-0806 (H)

GORE CITES SCIENTISTS' REPORT, CALLS FOR TOUGHER OZONE PROTECTIONS
Says Recent Findings Illustrate Urgent Need for Int'l Action

WASHINGTON-- The just-released findings of a team of international scientists -- confirming the threat of man-made chemicals to the earth's protective ozone shield -- reinforce the need for comprehensive legislation here and a new international agreement among countries around the globe to control those chemicals, said U. S. Sen. Al Gore, D-TN, who next month will travel to London as part of the U.S. delegation to an international conference on ozone protection.

"This report should and must act as an international catalyst to spark new discussions and more comprehensive action," Gore said. "The scientists are telling us that what they first suspected from laboratory blackboards is in fact happening in the real world. The chemicals we've created are creating serious problems with long-term environmental consequences for every person on the planet."

Gore is the author of the World Environment Policy Act of 1989, among the most comprehensive environmental protection proposals of this Congress, which confronts the broad array of culprits scientists suspect as responsible for the greenhouse effect and the destruction of the earth's protective ozone shield.

Gore's bill, for example, calls for a phased-in ban of chloroflourocarbons, the chemicals scientists have found to be responsible for the destruction of the stratospheric ozone.

"There is a clear need for Congressional action and recognition that the scientists findings must be translated into policies that will stop this devastation," Gore said. "We are facing the most vital environmental challenge of our lifetimes, of any time, and we cannot afford to hesitate or falter."

"We have the opportunity next month, in London, to begin the international discussions which will allow us to move beyond the Montreal Protocol to even more meaningful protections, " Gore

said. "It is my hope that the seeds we plant in March, will bear fruit in April when those nations who are parties to that protocol meet in Finland.

"Representatives of the 100 nations who will participate in London will have the opportunity to take back to their governments the need for strict new controls on CFCs, for a much faster timetable on the chemicals' ban than that provided for in the Montreal Protocol," Gore said. "We know much more now than we did when that protocoal was negotiated. It's time our policies reflected the full range of our scientific knowledge."

##

PHOTOCOPY
MISC. HANDWRITING

STATEMENT OF SENATOR ALBERT GORE

HEARING ON ARCTIC AND ANTARCTIC OZONE DEPLETION

SENATE SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

FEBRUARY 23, 1989

Today, the Senate, Science, Technology, and Space Subcommittee will examine one of the most serious environmental threats our planet faces -- the depletion of the stratospheric ozone layer.

We have all heard about ozone depletion over Antarctica. Today we will be hearing about new research which suggests that we should worry about oxone depletion in the Arctic as well. In addition, the Subcommittee will examine what is being done to get rid of the chlorofluorocarbons (CFC's) which are causing the problem.

We have with us three researchers from the recently-completed Airborne Arctic Stratospheric Expedition. More than 100 scientists spent the last two months in Norway, Greenland, and other parts of the Arctic, looking for evidence of an Arctic

PHOTOCOPY
MISC. HANDWRITING

ozone hole. Today we will hear a summary of their findings along with an update on the Antarctic ozone hole.

We all remember the surprising discovery of the Antarctic ozone hole a few years back. NASA satellite photos revealed a hole in the ozone layer centered around the South Pole. It was enormous -- larger than the United States. Within the hole, ozone levels were half their normal levels.

There are no voters in Antarctica to complain about the hole in the ozone. Most of the continent is cold, bleak, and lifeless. But even in the remotest place on earth, ozone depletion can cause problems. For example, the ocean around Antarctica is teeming with marine life which may be harmed by the UV radiation streaming through the ozone hole. Scientists are only now starting to assess the possible impact of the ozone depletion in Antarctica and elsewhere.

Furthermore, ozone depletion over Antarctica contributes to ozone depletion elsewhere. Not all the ozone lost in Antarctica is being replaced. Our first witness, Dr. Robert Watson, was chairman of the Ozone Trends Panel, which reported last March that ozone depletion was a global problem. Since 1969, ozone concentrations over the United States have decreased two to three

PHOTOCOPY
MISC. HANDWRITING

percent. That may not sound like much, but even such a small change could lead to millions of additional cases of skin cancer. It now appears that much of this decrease is due to ozone depletion over Antarctica.

We must come to understand the role the poles play in ozone depletion. I went to Antarctica last year to learn about the research being done there, and found that many questions remain. The Airborne Arctic Stratosphere Expedition was organized to answer some of those questions.

The scientists who have come here today ~~are our~~ are representative of those who first warned years ago ~~defense~~ against global environmental threats like ozone depletion. Recognizing what is happening to our planet will show us what measures we must take to halt the damage. We need a broad, international effort to monitor and understand the earth, so that we can respond wisely to the global environmental crisis -- from ozone depletion and global warming to deforestation and acid rain.

The Science Subcommittee is responsible for authorizing funds for global change research programs at the National Science foundation and at NASA. These programs, along with programs at the National Oceanic and Atmospheric Administration, have

PHOTOCOPY
MISC. HANDWRITING

provided much of what we know about the way our planet works. NSF and NASA have funded many of the long-term studies required to document man's impact on our planet. The pictures of the Antarctic ozone hole came from NASA's TOMS satellite. For years, NSF has funded atmospheric scientists working on increasingly sophisticated computer models to predict the effects of greenhouse warming.

The success of the Arctic ozone expedition was due not just to atmospheric scientists. They relied upon physicists, programmers, electronic engineers, and scientists from dozens of other disciplines. It would be a mistake to increase funding for research on ozone depletion at the expense of other disciplines.

In months ahead, the Science Subcommittee will consider the NASA budget. Numerous NASA satellites provide data that researchers need to monitor the health of our planet. The "Mission to Planet Earth" proposed by the Ride Report will provide badly needed data about our planet.These NASA programs should continue to be well-funded.

Later, we will hear from three manufacturers and users of CFC's, who will discuss the progress that has been made so far in finding replacements for CFC's. When I held hearings on ozone

depletion in the House more than five years ago, it was clear to me that it would become necessary to control production of CFC's. Since that time, world production of CFC's has increased markedly.

We can't wait any longer to address this problem. The Montreal Protocol, which the Senate ratified last year, put in place international limits on CFC production. But a 50% reduction in CFC emissions by 1999, as the Protocol requires, is too little, too late. * That is one reason I have introduced S. 201, the World Environment Policy Act of 1989, calling for a phaseout of the important ozone-depleting chemicals by 1996.

Man has set a terrifying chemical reaction in motion. I hope today's hearing will help inspire us to come to the defense of the ozone layer. The clock is ticking, and we have no time to waste.

* Later this month, I will travel to London as a member of a small U.S. delegation to an international conference that will ---

United States Senate

MEMORANDUM

19 May 89

Rick,

Here are a few more answers to follow-up questions from the ozone depletion hearing.

Mike

AIR-CONDITIONING
& REFRIGERATION
INSTITUTE

Arnold Braswell
President

March 29, 1989

The Honorable Albert Gore, Jr.
Chairman
Subcommittee on Science, Technology, and Space
United States Senate
Washington, D.C. 20510-6125

Dear Senator Gore:

Attached are my answers to the additional questions you sent to me on March 21 following my testimony February 23 before the Senate Subcommittee on Science, Technology and Space.

Sincerely,

Arnold Braswell

ARNOLD BRASWELL

AWB:meg

1501 [illegible] Boulevard, 6th Floor, Arlington, Virginia 22209-2403
[illegible]00 Telex 892351, Telecopier (703) 528-3816

ANSWERS BY ARNOLD BRASWELL
PRESIDENT, AIR CONDITIONING AND REFRIGERATION INSTITUTE
TO WRITTEN QUESTIONS IN SENATOR GORE'S LETTER OF MARCH 21, 1989

Question 1 (Senator Gore): Do your members believe that there will be delays in choosing energy-efficient CFC substitutes if NIST does not alter its schedule for producing high quality thermophysical data, but instead continues to give priority to use of its equipment to research being conducted for the Gas Research Institute on gas metering and for NASA/DOD on the space aeroplane?

Answer: ARI has asked NIST to accelerate its schedule for obtaining thermophysical data. We have been told that this can be done. I am not in a position to judge whether other NIST commitments will delay the research activity relating to refrigerants.

Question 2 (Senator Gore): Is ARI concerned about how various consortia of other nations sponsored by governments will affect the competitiveness of U.S. industry in air conditioning and refrigeration?

Answer: ARI members are indeed concerned that government-supported research in other nations will improve the competitiveness of foreign air conditioning and refrigeration products in the world market. ARI has developed a research plan which, with appropriate government support, will help to advance our industry's technology and help keep our industry products competitive. It was principally our industry's concern with the pace of foreign research that led ARI last year to establish a research and technology program, the first such program undertaken by our industry.

Question 3 (Senator Gore): Could the industry absorb about $20-30 million of R&D funds from the proposed fees being put on regulated CFCs?

Answer : ARI does not see the need at present for regulatory fees on controlled CFCs, but if such fees are imposed we believe that the revenues should be used to support appropriate research and development programs. Equipment manufacturers represented by ARI could put substantial funds to good use in various types of research to facilitate the transition to alternative refrigerants. There is much research and testing needed to identify new refrigerants and evaluate them for performance, compatibility with materials, safety and durability. The funds required for such a program require analysis but could approximate 20-30 million dollars a year. Other elements of the refrigeration and air conditioning industry (refrigerators, auto air-conditioners, foam producers, refrigerant producers) could also use substantial funds.

Question 4 (Senator Hollings): Any comprehensive strategy to cut CFC emissions will require developing CFC alternatives, developing new technology, and instituting CFC recycling programs.

- Which steps do you think will yield the largest reduction in emissions most quickly and for the least effort?

- Are there federal laws and regulations that are making cutting CFC emissions more difficult?

Answer (Part 1): Globally, the largest and earliest reductions in emissions could be achieved by banning the use of CFCs as aerosol propellants. In this country, where aerosols have already been restricted, there are few easy solutions. However, early and significant reductions may be possible in manufacture of foam, use of CFCs as industrial cleaners, and servicing practices for automotive air conditioners. Some reductions can also be made by reducing leaks and improving servicing practices for commercial refrigeration and air conditioning equipment.

Answer (Part 2): While I know of no federal laws and regulations which inhibit control of CFC emissions, there are a growing number of state regulations and interpretations which inhibit recovery and recycling of CFC refrigerants. A number of states incorrectly treat used CFC refrigerants as hazardous substances, thereby making it burdensome to recover and transport refrigerants to central locations for recycling. This leaves on-site emission as the easiest alternative.

Question 5 (Senator Hollinngs): I'd like to get your opinion of which parts of the transition to CFC replacements will be most difficult.

- Who do you think has the tougher job, the CFC manufacturers or the CFC users?

- Many different industries use CFCs. You represent makers of large refrigeration and air conditioning systems but CFCs are also used in household appliances, in foam blowing, and in computer chip making. Of the various users of CFCs, which ones do you think will take the longest to stop using CFCs?

Answer (Part 1): I believe that both the CFC manufacturers and the equipment manufacturers will have tasks of equivalent difficulty. Both of them will have to work together. Chemical manufacturers must provide adequate quantities of new substances and mixtures to the equipment manufacturers for research and testing. They must also conduct the lengthy toxicity testing required for these new compounds. Equipment manufacturers must test the new refrigerants for performance and compatibility, design new equipment, and then get it into production. As CFC refrigerants are phased out, service technicians in the field will have an increasingly difficult job keeping the installed inventory operating. Unless substitute refrigerants are found which can be used in the old equipment, it will no longer be serviceable and will have to be replaced. Government-funded research is needed to help find acceptable temporary substitutes for use in the old equipment while manufacturers concentrate on developing new products designed for new and different refrigerants.

Answer (Part 2): I believe that the large air conditioning chiller machines and the large commercial refrigeration systems will take the longest time to convert completely away from CFCs. Many of these systems last for 25 years or more. Phasing out CFCs in these machines

before they are replaced would require finding substitute refrigerants which will perform satisfactorily in them with little or no modification of the equipment. This is regarded as unlikely for the majority of the inventory.

Question 6 (Senator Hollings): A CFC phase-down will create new markets for CFC-free technology. I understand that Japanese air conditioning and refrigeration companies are spending quite a bit more than American firms on developing this new technology.

- Do you have any figures on the investments of U.S. and Japanese firms in this area?

- Are we going to let the Japanese take this market just like they have taken so many others?

Answer (Part 1): ARI has a current estimate of research and development expenditures by U.S. equipment manufacturers who belong to ARI. It approximates 20 million dollars in 1989 and will increase by 50% or more in 1990 and subsequent years. We do not have information on funds being invested by Japanese firms in this area.

Answer (Part 2): Our manufacturers intend to remain the leading world producers of this equipment and they are capable of doing so. U.S. laws and regulations affecting our industry and its products will have a great deal to do with this. Congress and the administration are capable of helping or damaging our industry's capability to remain globally competitive.

Question 7 (Senator Hollings): The National Institute of Standards and Technology has a program to develop new air conditioning technology that does not use CFCs.

- Have the members of your association found this program useful? Why?

- Should the Congress consider expanding it?

- How else can federal R&D efforts assist your industry as it makes the transition to CFC alternatives?

Answer (Part 1): Our industry considers NIST research on refrigerant properties to be extremely important and we have recommended that this work be accelerated and expanded. The NIST experimental work on new refrigeration technology may or may not provide usable technology; it is too early to tell.

Developing all of the technology involved in the task of converting to non-CFC refrigerants is a massive effort requiring the cooperation of equipment manufacturers, chemical manufacturers and organizations such as NIST as well as other government and private research entities.

ARI has urged NIST to accelerate and expand its refrigerant research activities as well as its planned program of assembling a repository of

technical information on new refrigerants. In fact, ARI is contributing funds in 1989 to permit expansion of this NIST activity for the benefit of the industry and has obtained agreement in principle by ARI members to provide non-proprietary refrigerant research data to the NIST repository.

Answer (Part 2): Congress should consider expanding the funds provided to NIST for refrigerant work, because their planned funding is inadequate. (No funds are in the 1990 budget for refrigerant activities). ARI believes that NIST should be provided with as much as three million dollars per year for the next three years for the purpose of research and technical assistance to industry in this area.

Answer (Part 3): There clearly are other ways in which the federal government could assist our industry greatly in expediting the transition to CFC alternatives. If there were plenty of time available, the industry could accomplish virtually all of the required research and development activity without federal involvement. However, we are facing the possibility of rapid phase-out of CFCs and the requirement for immediate development of new equipment using alternative refrigerants. This is a monumental task, because the number of candidate refrigerants is limited and there are strict requirements which they must satisfy.

In addition to the research on thermophysical properties being conducted by NIST, there is a pressing need for assistance in evaluating the compatibility of various new refrigerants with the many different materials and lubricants which are used in refrigeration and air conditioning systems. We have already learned that some of the promising refrigerant candidates have compatibility problems with the materials used in current equipment. Extensive additional research is needed and must be accomplished rapidly if we are to quickly identify the most satisfactory new refrigerants and then begin the detailed design and development work for the equipment which will use these refrigerants.

ARI has developed a research plan which addresses the research activities required to answer the compatibility questions. If federal funds were made available, ARI could administer a research program that would provide needed information to the industry on the chemical compatibility of new refrigerants with the materials, including lubricants, used in industry equipment. Such a program would be of immense benefit in expediting solution to the difficult questions which we face.

Question 8 (Senator Pressler): How much of an investment must your industry make in developing technology to use CFC substitutes? Might developing countries produce equipment that uses old CFCs if we abandon this market unilaterally?

Answer: No one can estimate now the total investment our industry must eventually make in developing technology to use CFC substitutes. It will most certainly be in the hundreds of millions of dollars, and this does not include the costs of retooling for producing new equipment.

When our nation stops making CFC equipment it is possible and perhaps even likely that some developing countries, particularly those which are not signatories to the Montreal Protocol, will continue to produce such equipment. This assumes that they will have an adequate source of CFC refrigerants. However, if the major industrialized nations switch to new refrigerants the technology for equipment using these refrigerants will soon spread to the developing countries as well. If there is an agreed environmental need to stop producing CFCs on a global basis, we should not be deterred by the possibility that some developing nations will delay conversion to the new refrigerants.

Question 9 (Senator Pressler): Will users of CFCs be able to "drop substitutes into" their equipment?

Answer: At this time we do not know of any substitute refrigerants which can be satisfactorily dropped into existing CFC equipment without any modification. It is possible that such substitutes can be found but most industry experts regard this as unlikely. It is more likely that all equipment will require some modification before it will operate satisfactorily and efficiently with a different non-CFC refrigerant. In some cases the modifications may be minor; in others they will be extensive. Because there is a vast inventory of CFC equipment installed, particularly large air conditioning machines and commercial refrigeration equipment, and because this equipment lasts for many years, the search for drop-in substitutes should have high priority. This is an area in which the federal government could be very helpful by conducting experiments and field tests on federal installations. Equipment manufacturers cannot pursue this type of research activity while heavily committed to developing new equipment for future production with new refrigerants.

Question 10 (Senator Pressler): Should we accelerate the schedule set forth in the Montreal Protocol? Should we take unilateral action?

Answer: Our industry will support acceleration of the schedule set forth in the Montreal Protocol if environmental scientists and political leaders are convinced that it is absolutely essential to do so in order to protect the environment. It will be important to weigh the economic and other effects of accelerated CFC phase-out against environmental needs in deciding on the extent of acceleration to be agreed upon. It would be a mistake, however, to take unilateral action. All efforts should be directed toward solving this problem on a global basis with at least the major industrialized nations participating.

Question 11 (Senator Pressler): What incentives should the federal government provide to make CFC substitutes affordable and useful?

Answer: I do not know of any federal incentives which are needed to make CFC substitutes affordable and useful. However, there may be a role for federal incentives of some sort to promote wide-spread reclaiming and recycling of used refrigerant. This is a matter which deserves study.

Question 12 (Senator Kerry): The following barriers to replacing CFCs

were listed by Dr. Glass in his prepared testimony:

— Incomplete or inconsistent thermodynamic and transport property information on all of the identified alternatives.

—Incomplete development of equipment that can use the alternatives.

— Signals at EPA and in the halls of Congress that some of the identified alternatives will have insufficient product lifetimes to justify the investment needed for us to produce them and for our customers to develop equipment to use them.

— High capital needs and an uncertain business climate.

— The need to complete development, evaluation and design of retrofit technologies so the current equipment which relies on CFCs (U.S. investment alone exceeds $135 billion) will serve for its useful life.

What is the status and our time table for overcoming each of these barriers, and how can the government, EPA, DOE and NIST help in speeding up the process and overcoming these barriers?

Answer: The timetable for overcoming the barriers described by Dr. Glas in his testimony will depend upon the CFC phase-out schedule and upon the completion of such activities as toxicity testing of new refrigerants. The government can help speed up the process by (1) establishing clear policies on refrigerant phase out and then sticking with these policies; (2) by avoiding burdensome CFC control regulations (such as auctioning consumption rights) which would disrupt the market and create artificial barriers to efficient distribution of the declining supply of CFCs; and (3) by conducting research and providing research funds to assist industry in identifying and proving the new refrigerants which will be needed.

Question 13 (Senator Kerry): DOE currently is in the process of promulgating new regulations for improving the energy efficiency of home appliances. At the same time, refrigerator manufacturers are concerned that they will soon be required to replace CFC refrigerants. I understand that these substitutes are not as energy efficient. This situation obviously has the potential to have a serious negative impact on the industry.

— Can you offer any suggestions for improving the regulatory process to reduce such conflicts?

— How can the industry become more constructively involved in the regulatory process?

Answer (Part 1): Resolution of conflicting or competing objectives in the regulatory process is a matter which necessitates informed discussion among the regulatory agencies and the Congress, leading to judicious decisions which take account of all needs. Important in this

decision process is recognizing up front which objectives are conflicting or competing with each other. That recognition has been missing from much discussion on the ozone depletion issue.

Answer (Part 2): I believe that the industry is constructively involved at the present time in the regulatory process.

Concerning efficiency standards, air conditioners which will be required to meet 1992 efficiency standards of the National Appliance Energy Conservation Act (NAECA) use HCFC-22 as a refrigerant. This refrigerant is not scheduled for reduction and should not be considered for control or reduction since it has a negligible effect on the ozone layer. It is also the fall-back refrigerant for many applications currently using CFCs if better alternatives cannot be found.

Question 14 (Senator Kasten): Shouldn't we stress the need for an international effort if we're going to control the technology of production of CFCs and their use in end products? Don't we have to guard against adopting a U.S. CFC ban, which could just result in having foreign countries continue to use ozone depleting products and the U.S. importing the end products? This would not only continue the environmental harm, but cause unilateral economic harm to the U.S. Could you comment on this please?

Answer: It would be very damaging and counter-productive for the U.S. to mandate the phase-out of CFC compounds at a faster rate than that accepted by other major nations. It would definitely cause economic harm to the U.S. industry. All efforts should be directed at securing a broad international agreement on the phase-out schedule.

Question 15 (Senator McCain): What percent of ozone depleting CFCs are used for air conditioning and refrigeration?

Answer: It is difficult to estimate accurately the total quantities of CFCs used for central air conditioning equipment and commercial refrigeration equipment included within the scope of ARI. The problem is that most of the consumption, perhaps 80%, is in field servicing to replace refrigerant quantities depleted by leakage or removed from equipment in the process of repair. ARI estimates that 10-15% of the total CFC consumption in this country is used in the types of equipment covered by our association. These are centrifugal air conditioning chillers; commercial refrigeration equipment used in restaurants, super markets, warehouses, industrial applications and transport containers; automatic commercial icemakers; and electric drinking water coolers. With improved methods of leak detection and prevention, and with an improved nationwide capability for reclaiming and recycling CFC refrigerants, I believe that total consumption for these products could be reduced eventually to 50% or less of current consumption.

Question 16 (Senator McCain): What effect will the 50 percent reduction in CFC production mandated by the Montreal Protocol have on the air conditioning and refrigeration industry?

Answer: The 50% reduction in CFC production scheduled for 1998 will

have a significant impact on the air conditioning and refrigeration industry if the largest consumers of CFCs have been unable to find alternatives which permit them to reduce their consumption by significant amounts. If such alternatives are developed the impact upon our industry and the public will be minimal, particularly as the industry begins producing new equipment using alternative refrigerants.

Question 17 (Senator McCain): What efforts is the industry making to improve CFC conservation, reclamation and responsible field practices to reduce ozone depleting emissions?

Answer: The industry is undertaking various efforts to improve conservation and responsible field practices to reduce CFC emissions. Manufacturers are designing equipment which will be less likely to leak and will be easier to service. The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) is developing guidelines for field practices designed to reduce CFC emmisions. Several manufacturers are producing refrigerant recycling equipment which can be used in the field to permit reclaiming and reusing contaminated refrigerant removed from systems.

Question 18 (Senator McCain): Do you know if students at air conditioning and refrigeration trade schools are made aware of the environmental problems of CFCs and taught how to handle these compounds conservatively?

Answer: ARI does not have detailed knowledge of the extent to which trade schools are being taught how to handle CFC compounds in order to reduce emissions. However, ARI plans in the near future to distribute an addendum to the ARI Curriculum Guide for trade schools which will recommend inclusion of such training.

Question 19 (Senator McCain): What could we do to improve these efforts?

Answer: ARI believes that effective efforts are underway to make technicians aware of the need for handling CFCs properly.

Question 20 (Senator McCain): What can we do to better reclaim CFCs contained in cars, air conditioning units and refrigerators which are scrapped?

Answer: CFC refrigerants in large air conditioning units will be reclaimed as a matter of course when such units are scrapped, particularly if the price increases or if reclaimed refrigerants are excluded from control as they should be. Reclaiming the small amounts contained in scrapped refrigerators and automobiles will be more difficult to insure. The best way to significantly reduce automobile emissions is to find a new refrigerant. The best way to reduce emissions from refrigerators is to find new insulation, since 80% of the CFC material in a refrigerator is in the foam insulation. The refrigerant in the foam as a practical matter cannot be recovered.

Question 21 (Senator McCain): I know that it is very important to CFC users that substitutes are "drop-in". For the record, can you explain

what is meant by a "drop-in" substitute and why it is important?

Answer: A "drop-in" substitute refers to a refrigerant which can be used in an installed piece of equipment without any equipment modification. The term does not apply to refrigerants used in redesigned equipment. The development of "drop-in" substitute refrigerants is critically important for commercial refrigeration and air-conditioning equipment because there is such a vast quantity of this equipment already installed. These machines will last for many years and will require servicing with CFC refrigerants from time to time unless suitable substitute refrigerants can be found. If CFC refrigerants are phased out by the end of the century and we cannot find "drop-in" substitutes for this equipment, the industry will have insufficient production capacity to replace all of the equipment before it goes out of service due to lack of refrigerant. This could result in shutting down refrigeration equipment in supermarkets, restaurants and other essential facilities and in shutting down large chiller machines used for essential cooling in office buildings, hospitals, hotels and other large buildings. There are currently no proven "drop-in" substitute refrigerants.

Question 22 (Senator McCain): How much time is needed for property, materials and toxicity testing before we can be sure a substitute is workable?

Answer: One of the principal delays to be overcome in testing new refrigerants is establishing a production capability to produce the quantities required for full scale testing and development. Toxicity testing takes thousands of pounds. Preliminary testing for refrigerant use will take hundreds or thousands of pounds while field testing in equipment will require additional thousands of pounds. It takes time to set up a pilot plant for quantities of this amount and the production costs are high. Once such quantities are available complete testing of properties and materials compatibility may take from two to four years depending upon difficulties encountered. Full scale toxicity testing will take five years or more, although it may not be necessary to complete the full range of toxicity tests before the refrigerant can be selected for use in certain applications and equipment design can begin.

Question 23 (Senator McCain): Is it proper to assume that if further reductions in CFCs are required, without the development of "drop-in" compounds, then CFC users will have to re-tool factories to accommodate nondrop-in substitutes which may be developed?

Answer: Yes, it is proper to assume that equipment manufacturers will have to retool to produce new equipment which uses alternative refrigerants. The extent of this retooling will depend upon how extensive are the design differences in comparison with the CFC equipment.

Question 24 (Senator McCain): Considering the cost, you would agree then that "drop-in" substitutes are a commercial as well as an environmental imperative?

Answer: I would agree that "drop-in" substitutes are a commercial imperative if a total phase out of CFC production by the end of the century is mandated. As to whether or not they are an environmental imperative, this depends upon whether or not it is mandatory to reduce CFC production to zero at an early date. If we cannot find "drop-in" substitutes, then we may find it necessary to continue producing a small amount of CFCs for refrigerant use to support the installed inventory (perhaps 5% or less of current CFC production) for a few more years after other uses are terminated. The alternative would be to shut down a lot of equipment, an action which would have severe economic consequences.

Question 25 (Senator McCain): Is there any indication that foreign companies are making any headway in the development of substitutes?

Answer: Foreign companies are beginning to test alternative refrigerants and some are believed to be about at the same level of development as U.S. companies.

Question 26 (Senator McCain): Do you believe that in light of the environmental and commercial importance of this issue, the federal government can and should increase its efforts in assisting the private sector to develop safe substitutes?

Answer: ARI believes that the federal government definitely can and should increase its efforts to assist the private sector to develop safe substitutes. This can best be done by providing federal funding for industry research programs and by increasing government research support.

Question 27 (Senator McCain): As you know, the Department of Energy, Environmental Protection Agency, Department of Commerce and the Department of Defense each have money and/or facilities for work on CFCs. I have proposed the establishment of a public/private sector task force to help devise, implement and coordinate federal efforts to facilitate the development of and transition to safe CFC substitutes. The task force would also examine ways we can reduce ozone depleting emissions through enhanced reclamation and conservation. Do you believe such a measure has merit?

Answer: There is a need for effective cooperation among federal agencies and departments to assist in the transition to alternative refrigerants. For example, there are federal facilities where substitute refrigerants could be tested in existing federal equipment to determine the suitability of these substitutes under field test conditions. With regard to facilitating the development of alternative refrigerants, our industry believes that some of the government-funded research and development work necessary to accomplish this could be effectively administered through the industry trade associations with federal funding support.

ARI would have no objection to participating in a public/private sector task force or coordinating committee, should one be formed, preferably one that is established as a vehicle to improve communication and avoid

duplication of effort. There is a risk that such a task force could operate in ways to obstruct rather than expedite progress in the search for CFC alternatives. It would be important to set it up properly so that it serves as a communicative and coordinating mechanism rather than as an executive body or an additional layer of bureaucracy with veto power.

National Aeronautics and
Space Administration

Washington, D.C.
20546

Reply to Attn of. XC:MDD:XC-00854f

MAY 16 1989

Mr. Marty Kress
Professional Staff
Subcommittee on Science, Technology
and Space
Committee on Commerce, Science
and Transportation
United States Senate
Washington, DC 20510

Dear Mr. Kress:

Enclosed are the final responses to written questions submitted by Senators Gore, Hollings and Kasten resulting from the February 23, 1989, hearing at which Dr. Watson testified on ozone depletion and global change.

This information completes the material requested during that hearing.

Sincerely,

Mary D. Kerwin
Director, Congressional Liaison Division

Enclosures

Responses to Written Questions Submitted by Senator Hollings.

Question 1: The Montreal Protocol set up a mechanism for periodic scientific reassessment of global ozone depletion. How well is the ongoing reassessment proceeding?

Answer 1: The reassessment is going very well. The first international assessment, required by January 1990 under the terms of the Montreal Protocol, is already underway and should be completed by the end of August 1989. The scope of the assessment has been determined, the participants have been selected, the chairmen have been chosen, and the schedule for writing and reviewing the document has been established.

Question 2: Given your experience as a participant in the negotiations that led to the original Protocol, do you think that the new evidence of increased ozone depletion will lead to amendments to the Protocol requiring faster, larger cuts in CFC production?

Answer 2: Since the Montreal Protocol was signed in September 1987, there have been three key scientific findings demonstrating that CFCs decrease ozone more than previously thought:

(1) The weight of scientific evidence strongly indicates that man-made chlorine- and bromine-containing substances are primarily responsible for the observed decrease in spring-time Antarctic ozone within the polar vortex.

(2) Analysis of data from ground-based "Dobson" instruments, after allowing for the effects of natural geophysical variability (solar cycle and the quasi-biennial oscillation [QBO]), show measurable decreases in the annual average of total global ozone from 1969 to 1986 ranging from 1.3% to 3.0% between 30-60 degrees in the Northern hemisphere. This decrease may be roughly two times larger than those predicted by photochemical models. Unfortunately, the short time period of the study and the small network of Dobson instruments make it very difficult to estimate how these changes relate to long-term natural global ozone fluctuations.

(3) The preliminary results of the recent expedition to Norway demonstrate that enhancements of ozone-depleting chlorine-containing substances do indeed occur in both the Arctic and Antarctic stratosphere, and represent an additional ozone-depleting process that was not included in the stratospheric ozone assessment models used as a basis for the Montreal Protocol.

It should also be noted that after recalibration of the Total Ozone Mapping Spectrometer (TOMS) aboard the Nimbus 7 satellite, a decrease in total column ozone of 2.5% "globally" (53 N to 53 S) was reported between October 1978 and October 1985. However, because of the shortness of the data record (less than one full solar cycle), it is not possible to unambiguously separate out the contribution due to natural variability (changes in solar output)

from that due to human activities (build-up of CFCs in the atmosphere).

All of these findings would need too be taken into account when considering amendments to the Protocol.

Question 3: The Montreal Protocol was the result of scientists and policymakers listening carefully to one another. This doesn't always happen. Why did it happen in this case?

Answer 3: Often the scientific community produces a number of sometimes conflicting statements, making effective policy determination and implementation difficult. However, in this case the essential ingredient was a unified international scientific assessment, and therefore only one scientific statement about the nature of the problem. This scientific assessment was based upon a strong research effort, particularly in the U.S. Also in this particular case, a number of scientists were able to communicate their perceptions of the problem and potential solutions in language that the policymakers could understand.

Question 4: I understand that the Chemical Manufacturers of America provided research funding for both the Arctic and the Antarctic ozone expeditions. Has CMA shown a long-term commitment to funding research to address environmental issues? Do you feel that their financial participation in the process in any way compromises the credibility of the scientific findings?

Answer 4: The CMA has a special panel for CFC research called the Fluorocarbon Program Panel comprised of nineteen producer companies from North America, Europe, Japan, and Australia. This panel only conducts scientific research, not advocacy. They have contributed about one and a half million dollars each year for the past fifteen years toward CFC research.

We do not feel that CMA's financial participation in any way compromises the credibility of their research. The scientific research of the Panel is beyond reproach. The Panel funds scientists from the best universities around the world, including U.S. scientists that NASA and the NSF would otherwise fund. The Panel's peer review process for proposals is similar to that of NASA's. The Panel does not censor scientific findings, and their publishing standards meet or exceed those found in other respectable scientific institutions. Their advisors have included Nobel prize winners such as Dudley Hershbach. The CMA funding is extremely important to CFC research since it funds much of the non-U.S. component of international activities, which NASA cannot do.

Question 5: I noticed that the Arctic Ozone Expedition did not receive funding from EPA, the agency responsible for regulating CFC production. Why is that? In general, how important is it that the science be independent of policy?

Answer 5: Funding was not requested from EPA. NASA and NOAA have a congressional mandate and the funding to study the physical and Chemical processes that control atmospheric ozone. EPA has

primary responsibility for policymaking, and for monitoring how human health and ecosystems will respond to changes in the ozone.

It is extremely important for science to remain independent of policy. Scientific research and data must be viewed to be above reproach and totally uncompromised. Science agencies need longer time horizons for planning and implementing scientific programs than the day-to-day needs of policy often allow. This can be most easily accomplished through a clean separation of policy and science. Indeed, the reason that NASA, in collaboration with NOAA and NSF, could study polar ozone so rapidly and effectively was the commitment of the U.S. government to a comprehensive, long-term research program. It is expected that this collaboration be even further strengthened through the interagency research planning efforts of the Committee on Earth Sciences.

Question 6: As we phase down CFC production we need to make sure that the chemicals we use to replace CFCs are environmentally safe. The United States presently produces millions of pounds of CFCs annually, so in the future we will clearly have to produce millions of pounds of CFC replacements. How confident are we that the CFC replacements now being tested will not cause environmental damage when released into the atmosphere? What kind of research is needed to make sure these replacements do not cause more environmental damage than the CFCs they replace? How long would such research take?

Answer 6: The scientific community is critically analyzing the environmental impacts of all known potential substitutes. Industry (through the Alternative Fluorocarbons Environmental Acceptability study) and government science agencies are currently collaborating on the problem, analyzing substitutes for their impacts on tropospheric and stratospheric ozone, global warming, acid precipitation, human health, etc. A critical assessment will be available by mid-May when Dr. Robert Watson will chair an international review of the evaluation of potential environmental damage by CFC substitutes.

While there is a reasonable scientific data base concerning some aspects of the potential substitutes, there are clearly some scientific uncertainties associated with the potential environmental impact of CFC substitutes. The scientific community needs to perform additional detailed laboratory studies to determine how quickly these substitutes will deteriorate in the troposphere and what the optical properties are that could lead to greenhouse warming.

With the exception of toxological testing, most of the important data related to the environmental impacts of CFC substitutes could be obtained within a year or so.

Responses to Written Questions Submitted by Senator Kasten.

Question 1: I understand that with respect to the CFCs, which are the general classification of the substances which cause ozone depletion, that there are some which are much more damaging than others. Also, I understand that there are other substances, which are not CFCs, which have been found to contribute to the problem. As we look toward developing policies on the use of ozone depleting substances, could you comment on whether there are some CFCs which are more damaging than others and whether there are other substances beyond the CFCs on which we should begin to focus?

Answer 1: The most damaging CFCs are the fully halogenated CFCs: those that contain carbon, chlorine, and fluorine but no hydrogen. These chemicals have atmospheric lifetimes of approximately one hundred years. Fully halogenated CFCs are used as refrigerants, foam blowing agents, and solvents. Other chemicals that contribute to ozone destruction are the halons, those bromine-containing substances used as fire retardants.

The Vienna Convention on ozone depletion noted that carbon dioxide, methane, and nitrous oxide all control atmospheric ozone. Increases in carbon dioxide and methane will increase atmospheric ozone, whereas increases in nitrous oxide will lead to ozone depletion. However, it is important to note that methane increases ozone levels in the troposphere near the ground. High ozone levels near the ground are toxic to human health, and will contribute to global warming.

Industry is planning to replace fully halogenated CFCs with partially halogenated CFCs, ones that will either contain hydrogen or will not contain chlorine. The CFCs with chlorine and hydrogen have short atmospheric lifetimes, so that large concentrations of chlorine cannot accumulate in the atmosphere. These hydrogen- and chlorine-containing substances will be ten to fifty times less effective in destroying the ozone (i.e., cause much less damage) than the CFCs they will replace. Therefore, to best limit the damage already done to the ozone layer, the regulations on fully halogenated CFCs currently included in the Montreal Protocol need to be strengthened, calling for close to a complete phase out on use of those molecules. These regulations would also need to include restrictions on the use of carbon tetrachloride, methylchloroform, and other chlorine-containing chemicals.

It must be noted that while there is a clear need to study the atmospheric and environmental impacts of gases such as carbon dioxide, methane, and nitrous oxide, the regulation of these substances is more difficult than regulation of CFCs because they are used and produced in agriculture and energy-related activities. These gases all contribute to the predicted global warming.

Responses to Written Questions Submitted by Chairman Gore.

Question 1: Does the observed [ozone] depletion at 19-20 km at many latitudes in any way support the hypothesis that heterogeneous chemistry may be taking place in the so-called "aerosol layer" of the ozone layer? What is the magnitude and timing of all of NASA's efforts to resolve this issue?

Answer 1: It is possible that heterogeneous chemistry may be taking place in the "aerosol layer." NASA is currently conducting laboratory, field, and theoretical efforts to understand this issue. We continue to monitor ozone through satellite observations, and are aggressively performing laboratory studies of heterogeneous processes to attempt to simulate the potential impacts of those processes using the best theoretical models. In the next year or so, we plan to conduct aircraft observations at the mid-latitudes, in the same manner as in the Antarctic and Arctic campaigns, to determine if there is any direct evidence of the mid-latitude aerosol layer actually causing reductions in atmospheric ozone.