

if this is done immediately, the problem will persist for decades, and in fact will almost certainly worsen over the next 10 or 20 years. We need effective "Band-Aid" solutions as soon as possible.

It is not technically conceivable that we can scavenge chlorofluorocarbons and halons from the atmosphere, simply because they are diffused in low concentration through the immense volume of the whole atmosphere. That would require "Star Trek" technology that will not be available for centuries to come, if ever. However, the polar stratospheric clouds, as large on the human scale and inaccessible as they are, occupy a relatively small proportion of the total atmosphere and thus offer a possible focal point of attack on the cycle of ozone breakdown. It is within the remote limits of conceivability that we might be able to somehow dissipate or melt these clouds or otherwise interfere with the surface-mediated chemistry that occurs in them, at least to a degree that might significantly mitigate the ozone breakdown.

There are a few obvious possibilities: Maybe one could inject into the clouds by high-flying aircraft a material that would either darken the ice crystals enough to cause them to melt or evaporate, or alter their surface properties in such a way as to discourage the harmful reactions. Maybe there is a way one could direct radiant energy onto them during those critical days or weeks at the ends of the polar winter, perhaps using land- or orbital-based mirrors or lasers. (There's a good use for the resources and talent now being squandered on SDI and ICBMs.) Maybe the crystals themselves could be scavenged in some way, or the clouds broken up or diverted to lower altitudes.

All of these suggestions are improbable, and yet they are sufficiently within the limits of bare possibility that they might merit more detailed investigation. I hope that atmospheric physicists, space scientists and others who might be competent to implement them will give them at least a passing thought.

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3/92

HAMILL AND TOON REPLY: The eventual solution to the ozone hole problem is to stop injecting long-lived chlorine compounds into the atmosphere. World leaders have already taken this course, and in a century or so nature should have repaired itself. Over the next decade, however, chlo-

rine levels will continue to rise and ozone loss will worsen globally.

The particular temporary solutions suggested by Kent Peacock do not appear to be practicable. For example, spraying the clouds with soot would not help, because during the crucial time period the clouds are not exposed to sunlight. Similarly, it would be difficult to use lasers or mirrors to melt the particles, because they are in contact with the atmosphere, and it would be necessary to heat a substantial portion of the atmosphere. Energetically, that is not feasible.

Unfortunately, no obvious solution is known, particularly since ozone loss is occurring globally and not just over Antarctica. However, several scientists have suggested possible temporary solutions. For example, Ralph Cicerone, Scott Elliott and Richard Turco recently calculated that annual injections of 50 000 tons of ethane or propane into the lower stratosphere would cause enough active chlorine to be transformed to the reservoir species HCl to effectively short-circuit ozone hole formation.¹ However, it would be difficult to transport these substances to the stratosphere and to mix them uniformly with the air. Furthermore, this would do nothing to mitigate the ozone loss occurring over the Northern Hemisphere. Even more significant is the fact that such injections might not perform as expected. Some calculations indicate that lower levels of propane injection would actually increase ozone loss.

Although there do not seem to be any realistic short-term solutions to the problem, this is a subject in which debate and an interchange of ideas are certainly welcome.

Reference

1. R. Cicerone, S. Elliott, R. Turco, *Science* **254**, 1191 (1991).

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7/92

Nuclear Waste Cures: Hanford and Beyond

The nasty problems associated with the management of accumulated high-level radioactive waste at the Hanford nuclear facility (and their urgency) have been eloquently set forth by Barbara Goss Levi (March 1992, page 17). While most of them seem to have no simple solution, one of the acute problems described appears

to have one that can even produce useful products and that does not seem to require the lengthy preliminary studies needed to tackle so many of the others. I refer to the danger of hydrogen explosions in the facility's 177 million-gallon storage tanks.

Hydrogen produced by radiolytic decomposition of water (and some organic compounds) apparently builds up in some tanks despite the ventilation system that adequately serves others. Simply venting those tanks is an obvious expedient that would occur to anybody, so I presume there must be serious objections to doing so, such as the need to prevent the egress of poisons or the entry of hazardous atmospheric constituents (for example, oxygen, which might fuel explosions). Assuming hydrogen is the culprit, there is a well-known method for bleeding it off selectively without allowing anything else to come in. I refer to the permeability of palladium to hydrogen. In the "good old days" a standard laboratory technique for introducing pure hydrogen into a vacuum system was to use a palladium "needle." Illuminating gas contained enough hydrogen so that a gently warmed hollow needle would act as a semipermeable membrane, passing hydrogen from the gas supply into the system and blocking all else. Because the hydrogen passing through would be pure, and tritium and deuterium are essentially the same as ordinary hydrogen in their ability to diffuse through Pd, one could easily collect potentially valuable byproducts.

Of course one would have to breach the container wall to attach the needle, which could be bothersome under existing conditions. But if the hydrogen problem is really serious, this would be only a temporary nuisance, well worth overcoming.

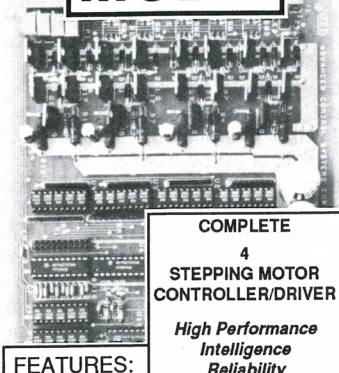
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3/92

I greatly appreciated Barbara Goss Levi's informative news story on the potential hazards due to nuclear waste at the Hanford facility. It is evident that a number of people are concerned about the situation and are taking appropriate action to deal with this unfortunate legacy.

The news story emphasized that no one has found an adequate long-term solution to the problem of nuclear waste. I would suggest, however, a very simple solution: *Don't make it!* Of course this does not help Hanford now, but all of the future Hanfords could be eliminated by a little foresight. I do not wish to belittle the complexity of the political decisions

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made during the cold war years. Nevertheless, one cannot help but notice that weapons research has found a comfortable niche in the world of government funding. During times of war, new technologies are needed, while times of peace bring the need for someone to clean up the mess.

Hanford should remind us all that scientists can never be totally objective observers; we are destined to leave our marks wherever we go. Thus it behooves us to consider carefully where to direct our talents and efforts, perhaps even placing "unscientific" factors such as politics and morality over job security.

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5/92

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Global Warming and Atmospheric Altimetry

The consensus of the scientific community about global warming developed after painstaking compilation of long-term measurements of surface temperatures at a wide range of locations. This statistical approach, although valid, allows some well-meaning and responsible scientists to express reservations about the magnitude of the warming and its ultimate impact on the Earth's climate. Unfortunately, some politicians have seized on that slight doubt and used it to block, whenever and wherever possible, progress toward correction of the problem. One potential way of overcoming this obstacle is to explain and prove global warming in such simple terms that even the most politically motivated Luddite would understand.

The simplest approach is to consider the entire atmosphere as a single system and apply the ideal-gas law,

$$PV = nRT$$

to it. An appropriate way to proceed is then to examine each term and to look for any evidence indicating drastic change.

▷ T is the absolute temperature. If it is rising, there must be a corresponding change in another element of the equation.

▷ R is a constant. It will not change.
▷ n is the number of moles of the gas and is proportional to the number of molecules in the gas. When a carbon atom is burned to produce carbon dioxide, a molecule of diatomic oxygen is consumed. Thus combustion and animal metabolism, the two major sources of carbon dioxide, are neither creating nor destroying gas molecules.

▷ P is the absolute pressure. Atmospheric pressure results from the

Earth's gravity. There will be no massive change here.

▷ V is the volume of the atmosphere. If the atmosphere is warming, there should be a corresponding increase in the volume, as the only constraint is gravity. One place to look for such an increase is in space satellite orbit data.

At the time of the Hubble Space Telescope launch, 24 April 1990, NASA mentioned in its announcements that the telescope's designed lifetime of 15 years would be reduced to 5 years because the atmosphere had expanded. Within days, that comment was deleted from the announcements. As this was long before the system was tested, the decision could not have been due to any concern for the subsequent imaging problems.

The NASA reports, if unclassified, should be available to anyone who has the access to the agency's database. Various researchers who have been monitoring surface temperatures will be able to corroborate their own measurements. Thus, with this macroscopic "yardstick" we will finally have a basis for agreement not only on whether global warming exists but also as to the magnitude of the effect. It makes sense that a global effect should be measured on a global scale. The "altitude" of the atmosphere is such a global measure.

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3/92

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Is the 'Feynman Effect' a Misnomer?

In his Opinion column "The Feynman Effect and the Boon Docs" (January 1992, page 67) Albert A. Bartlett called our attention to the phenomenon of "directing one's teaching toward colleagues when one is supposed to be focusing on freshmen" and its effect on national scientific literacy. I know not the extent to which the two are correlated; however, to label the former the Feynman effect is grossly inaccurate and totally inappropriate.

As an undergraduate (1959-63) and graduate student (1963-66) at Caltech I witnessed firsthand Richard P. Feynman's extraordinary ability to discuss anything with anyone in his or her own technical language. In all of my seven years there I never witnessed Feynman, or for that matter any other professor, "teaching to his colleagues," nor did anyone ever complain of this.

Bartlett bases his definition of the effect on a passage from David L. Goodstein's article in the special issue