Cooling the Greenhouse

By Osayuki Yokoyama

Global warming, the greenhouse effect, is caused not only by carbon dioxide (CO_2), but also by several other gases that include methane (CH_4), dinitrogen oxide (N_2O), chlorofluorocarbons (CFCs), carbon tetrachloride (CCl_4) and nitrogen dioxide (NO_2).

Alleviation of the greenhouse effect requires the curtailment of gases that persist in the atmosphere. Controlling CFCs is important not just for protection of the stratospheric ozone layer but also for resolving the global warming problem.

Research by a group of scholars based on a climatic change model suggests that if the increase in gas concentration in the atmosphere as of 1980 continues, about half of any temperature rise would be caused by gases other than CO_2 in the year 2030. CFCs, which have an estimated 100-year life in the atmosphere, could cause 25% of the warming. A complete ban on CFCs scheduled for 2000 will help alleviate the warming problem, but it is necessary to work out a warming projection in light of the new CFC rule.

In Japan, universities and government-run institutes have been assessing the influence of gases on the greenhouse effect. M. Tanaka reported in 1986 that he had measured CO_2 levels aboard aircraft and ships on Japan-Australia routes since 1979. Japan's Meteorological Agency began measuring CO_2 levels at Ayasato, Iwate Prefecture in 1987, as part of a gas background concentration measurement program of the World Meteorological Organization. These data showed that the CO_2 level was 345 ppm (parts per million) and rising at an annual rate of 1–1.3 ppm. Other data also point to a similar trend.

In addition, CO_2 remote sensors will be installed in the *ADEOS* (advanced earth observing satellite) which the National Space Development Agency of Japan will launch within fiscal 1995. The sensors will measure CO_2 concentrations around the earth.

K. Tominaga and his team reported in 1987 that the CFC concentration in the air was rising from year to year. Annual changes of methane and dinitrogen oxide have also been measured. It is not entirely clear what causes the rising gas concentration. Nonetheless, these surveys showed that the gas concentration, blamed for the warming, is increasing every year.

Climate change

A change in the Japanese climate is evidenced by various studies, including Meteorological Agency reports on abnormal weather. The agency data indicated that the average ground temperature has been rising in many places for the past 30 years. It should be noted, however, that most of the agency's observation stations are located in larger cities. Therefore, it is difficult to judge exactly what caused the warming: CO_2 or urbanization. The data also show that the relative humidity shows a downtrend at many sites. This may be safely attributed to urbanization, particularly paving of roads.

According to measurements by the Aerological Observatory, the tempera-

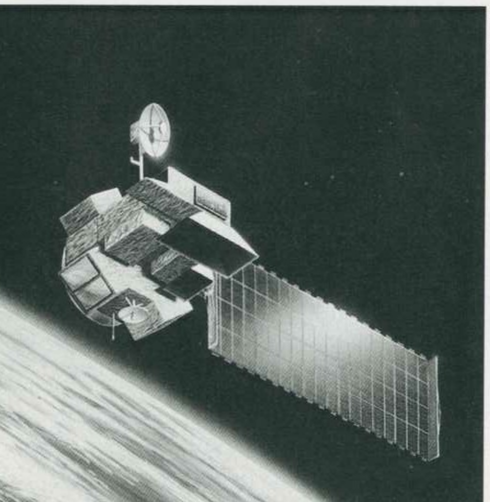
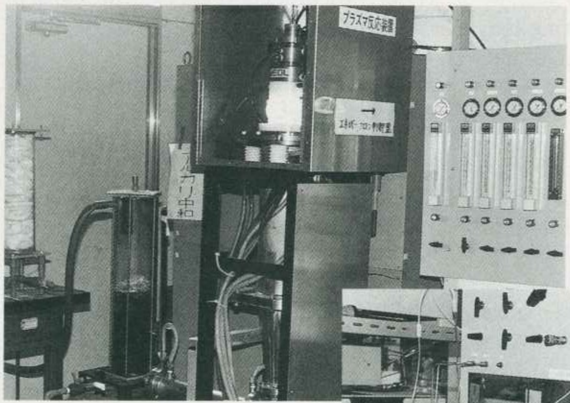


Photo: NASDA

ADEOS (advanced earth observing satellite)



CFC destruction system

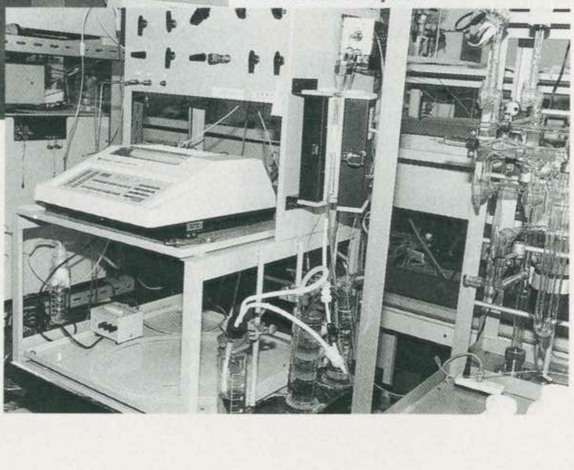


Photo: Asahi Shimbun

Pollution-free automobiles are being eagerly developed.

ture in the troposphere (12–13 kilometers above the earth) is tending to become higher, while the temperature in the stratosphere shows a downtrend. This conforms with the general trend of temperature change caused by warming gases.

Temperature, humidity and wind, as observed by the ground observation stations, are inevitably susceptible to changes in the surroundng environment. By comparison, the number of high and low air pressures in a given year serves as data that suggest climatic changes on a large scale. Annual changes of high air pressures in the Northern Hemisphere for the past 10 years or so show that they appear less frequently. It is difficult to link this phenomenon to the global warming. But the data do show that a global climatic change is taking place.

It is possible to forecast the rise of global average temperatures by using average temperature distribution and taking into account the absorbing bands of solar and infrared ray frequencies. There are several unidimensional models based on this scheme. These models generally try to forecast average temperature rises when CO_2 gas concentration doubles. These unidimensional models are used to forecast temperature changes according to changing gas levels.

More complex models have been made that consider many more elements than the unidimensional models. These larger models—general circulation models—divide the earth into land and oceans and deal with the great atmospheric circulation between the atmosphere and oceans by dynamic methods. These models also cover, among other things, absorption of light, clouds, aerosol gases, rain, humidity and reflections on the earth's surface. They forecast changes not only in temperature, humidity and rain but also in the deserts and in the icebergs in the Arctic and Antarctic regions.

The model makers in Japan include T. Tokioka, a researcher with the Meteorological Agency's research institute. The general circulation models try to predict a number of phenomena, including temperature rises, changes in sea surface levels, moving of warm and moist regions and deserts, and rainfall by areas. But the reliability of the forecast is still open to question.

Controlling emissions

The existing technology for CO_2 emission control includes energy saving, efficient utilization of energy sources, shifting to light fuel and use of renewable energy sources. The future technology that is now conceived includes CO_2 recovery, solidification and repeated use of CO_2 as fuel.

Energy saving and efficient energy use

Since the crude oil crisis of 1973, technological development in both energy conservation and efficient use of energy have been aggressively carried out in Japan by industries and commercial entities, including the transportation sector, and even in individual homes. Major technology for CO_2 emission control will include:

(1) Industry
- Recovery of waste heat by heat pumps and super heat pumps
- Twin-energy systems, i.e., the combination of fuel cells and air-conditioning systems
- Combined cycles for power generation
- Power generation by blast-furnace gas
- Power generation by cold energy from liquefied natural gas

(2) Commercial premises and homes
- Regional air-conditioning
- Improvement of insulation
- Development of high-efficiency electrical equipment

(3) Transportation
- Development of high-efficiency engines such as ceramic engines
- Development of vehicles with better fuel economy
- Rationalization of traffic and transportation systems

Renewable energy

The New Energy Development Organization (NEDO) and private companies are trying to develop such new energies as wind power, geothermal energy, biomass, solar energy (light and heat), sea-currrent and tidal power.

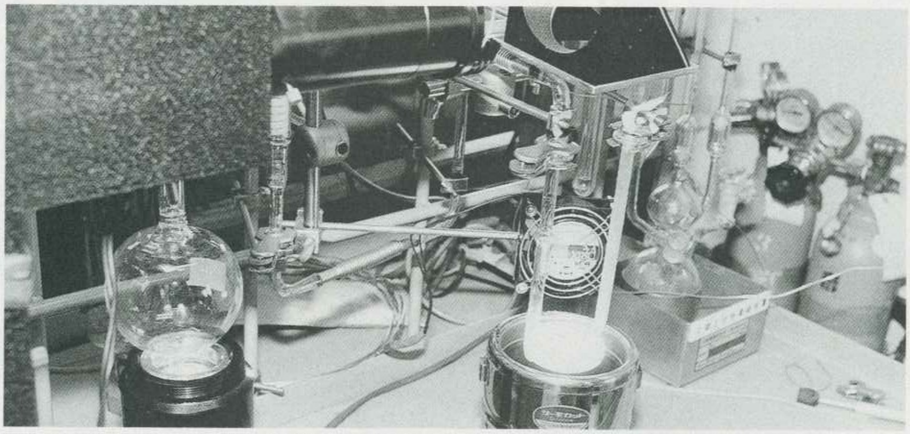
Light fuel

Shifting from coal to petroleum, natural gas and other light fuels containing higher levels of hydrogen is being tested. This is not exactly the development of new technology, as similar attempts have been made in the past. Economical efficiency involved remains a problem.

Treatment of CO_2 gas

It is now fairly well-known how much CO_2 gas circulates in the air, ocean, plants and underground. Also, it has long been known that plants fix CO_2 gas. The major problem is that man produces about 20 billion metric tons of CO_2 gas a year, far more than plants and the oceans can deal with. As a result, the untreated gas seeks its way to the atmosphere, raising the gas level there.

Planting new trees will not fully resolve the problem, as was suggested by Y. Kaya


Photoreduction system of carbon dioxide that turns gases such as methane into fuel

in 1989. It will be necessary to develop chemical or physical processes to recover, eliminate or fix CO_2 gas in the air. At present, such technology is absent. But CO_2 is already used as a raw material for chemicals. CO_2 can be removed from various sources, including natural gas, combustion and ammonia synthesis gas. These existing technologies may be applied to solve the CO_2 problem, and new technologies may be developed, such as artificial photosynthesis and biological routes.

(1) Absorption

Amine solvents absorb CO_2 efficiently at room temperature and in low pressure. Y. Kaya has conceived technology which can absorb CO_2 from combustion gas at room temperature and in normal pressure, by heating the CO_2 to raise its concentration. The highly enriched gas may be disposed of in deep seas or oil fields, according to Kaya. Also, hot potassium carbonate solution is known to absorb CO_2 at high pressure.

(2) Adsorption

Amine resins, and natural or man-made zeolite adsorbs CO_2 well. Various technologies may be developed to have the adsorbents adsorb CO_2 at room temperature and recover the gas by heating. CO_2 may also be recovered through cyclical changes of pressures.

(3) Separation by membrane

CO_2 gas may be also separated by a membrane made from cellulose acetate, polyimide or silicone rubber. This technology makes use of the fact that different gases pass through membranes at differing rates.

(4) Fixing

CO_2 gas may be made to react with a strong base so that the gas may be fixed as calcium carbonate or other chemicals. For example, reaction with caustic soda would produce sodium bicarbonate, and reaction with calcium oxide or calcium hydroxide would produce calcium carbonate.

Another method would be the reaction of CO_2 with a solution of an alkaline metal's hydroxide for the production of carbonate of the metal. In this case, it would be necessary to calculate in advance the energy requirement for the production of these chemicals as well as the volume of CO_2 gas generation.

(5) Artificial photosynthesis

Various technologies can be conceived. For example, the National Research Institute for Pollution and Resources is trying to develop a process in which a semiconducting metal will produce methane from CO_2 gas. The source of energy for this reaction would be ultraviolet rays from solar light. The methane produced may be used fixed as methanol or as a fuel.

(6) Biotechnology

This category includes raising coral so that its calcium carbonate can fix CO_2. Similar fixing technology may be possible with green, red and brown algae in the sea.

Other measures to deal with greenhouse effect

The use of CFCs is being banned because they contribute heavily to the global warming and to destroying of the stratospheric ozone layer. But there is no guarantee that alternative substances will not cause the same problem. Besides, some CFCs may remain because substitutes cannot be developed at present. Thus, it is necessary to develop a technology which can recover or crack CFCs.

The National Institute for Pollution and Resources developed two methods of cracking CFCs and is working to put the technology into practical use. First, adsorbents, such as zeolite, are used to recover CFCs by adsorption technology. The CFCs thus separated may be destroyed by two processes. In the first process, CFCs are treated with water before they are cracked by a plasma furnace. In the second process, a catalyst is used for cracking. These processes will effectively destroy other gases, including methane, dinitrogen oxide and carbon tetrachloride.

Research effort

The oil crisis of 1973 has prompted aggressive energy research efforts by NEDO and other institutes affiliated with the Agency of Industrial Science and Technology (AIST) of the Ministry of International Trade and Industry.

There are two key projects: the Sunshine Project and the Moonlight Project. Sunshine is aimed at developing alternative energy sources, such as geothermal, solar and wind power. Moonlight is directed at energy conservation and efficient use of energy.

When the two research projects were launched in 1976, global environmental problems had not yet surfaced. But in retrospect, both the Sunshine and Moonlight Projects were closely linked with the CO_2 problem. The waste-heat recovery and twin-energy projects in Moonlight are directly aimed at mitigating CO_2 gas emission. Sunshine's geothermal, solar, wind power and biomass efforts aim to develop "CO_2-free energy."

The AIST-run institutes will begin research to recover, eliminate and fix CO_2, during the current fiscal year. The most important aspect of the research will be how to combine these technologies and develop a CO_2 emission control system without causing the global economy to slow down.

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