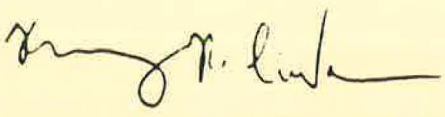
needed to determine by late 1983 the technical and economic feasibility of producing methane from seaweed. A conceptual commercial design study should also be undertaken. GRI agrees and has requested proposals for such a study.

- GRI should play an active role in determining well in advance what effect new appliance technologies will have on existing emissions standards. This effort will be helpful in planning developments to ensure that new products can be successfully introduced into the marketplace. ITAC currently includes a liaison member from the Gas Appliance Manufacturers Association (GAMA), and GRI plans to establish further communications with the appropriate standards groups at GAMA.
- Standard test procedures for evaluating the performance of new heating and cooling appliances should be developed. GRI has begun the selection process for an ad hoc committee to establish such a procedure.

GRI is implementing these recommendations as well as many others submitted by the PAG's. The continuous input provided by the advisor groups throughout the year has also helped to strengthen and guide GRI's entire program. Without their valuable and appreciated assistance, GRI would be unable to fulfill its important responsibilities to the gas industry and ratepayer in an efficient and effective manner.■



Henry R. Linden

Project Advisor Groups

Fossil Fuel Gasification	Non-Fossil Gas Sources	Unconventional Natural Gas	Liquefied Natural Gas
Distribution	Space Conditioning	Solar/Gas Energy	Fuel Cells
Gas Appliances	Industrial Utilization	Heat Pumps	Environment
Basic Research	Energy Economics	Safety	Cogeneration

Indoor Air Quality

AIC 679

#1108

by **Donald O. Johnson,** *Assistant Director, Environmental Research, and* **F. Richard Kurzynske,** *Manager, Environmental Assessment and Control, Utilization*

Completed studies indicate that emissions from indoor sources, including those from unvented gas appliances, do not cause any undesirable effects in buildings with normal ventilation rates. However, recent energy-conservation measures aimed at reducing ventilation rates have created the need for new, more detailed data on the indoor environment. GRI has initiated a program to collect such data, and if a need exists, to develop appropriate control techniques even though unvented gas appliances pay a small part in the overall picture.

The character of the indoor air environment is extremely complex. Normal household activities, for example, present a near endless variation in both the sources and concentration of pollutants. Smoking, cooking, cleaning, pets and children at play—all can produce significant amounts of particulates and undesirable compounds. In addition, outdoor air pollution in the vicinity of the home and the rate of outdoor-indoor air exchange are important, but difficult to quantify, factors.

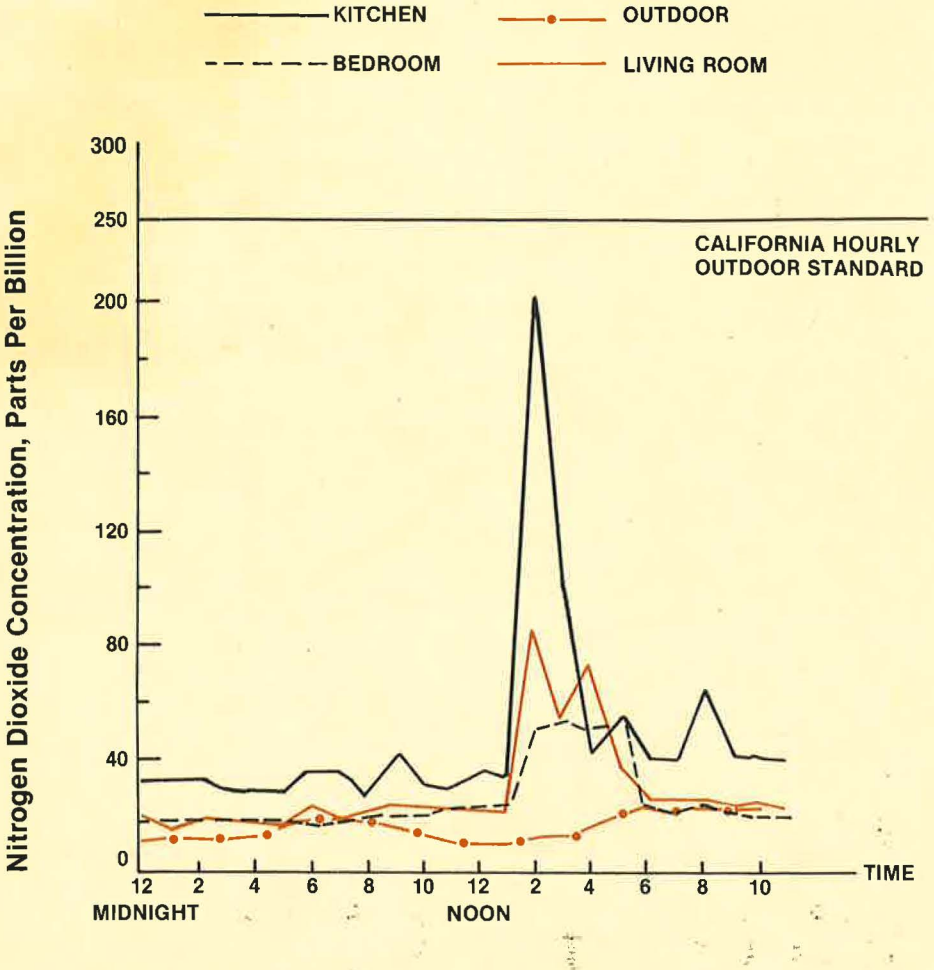
Although many studies on indoor air quality have been performed during the past decade, the magnitude and range of the factors mentioned above have precluded the accumulation of definitive data that could lead to reliable conclusions. For example, unvented gas appliances have been found to emit nitrogen dioxide (NO_2) as a normal product of combustion. This substance is produced in small amounts which, under customary operating conditions, is not harmful to human health. The accompanying figure shows typical concentrations of NO_2 in various rooms of a home with an unvented gas range as well as at a nearby outdoor location. The hourly variation of NO_2 concentrations is typical of the majority of residences. This figure demonstrates that while the indoor NO_2 concentrations are higher than the corresponding outdoor levels, the indoor concentrations remain lower than the California hourly outdoor ambient standard of 250 parts per billion. GRI recognizes that outdoor standards are not applicable indoors, but the comparison has been made in this case because the California standard is the only available reference point for short-term exposures to NO_2.

Emissions from unvented appliances using other fuels should also be totally characterized for their effect on the indoor environment. Of course, furnaces, water heaters, and other equipment whose combustion products are vented to the outdoors have little or no effect on the indoor environment.

Data Needed

In order to fully understand the complex relationship between the indoor environment and health, four types of data must be collected and analyzed: 1) source strength emissions—the amount of any emission produced at the combustion source; 2) the level or concentration reached in a room as the source emission mixes with room air; 3) an individual's exposure to the emission—how much of the emission a person is subjected to over a given period of time; and 4) any effects that inhaling or contact with these emissions may have on an individual's health. The last type of study, when performed on a selected population, is known as an epidemiology study.

In previous studies undertaken to determine the potential effects of NO_2 and other emissions from unvented appliances



Hourly Concentration of Nitrogen Dioxide at Three Locations and One Outdoor Location Adjacent to a Residence with an Unvented Gas Appliance. (D. J. Moschandreas, to be published in Transportation Engineering Journal of American Society of Civil Engineers, October 1982)

on health, various monitoring designs were followed, different sampling instruments used, and separate objectives sought. These disparities made comparisons among the studies difficult, if not impossible. Information from these studies is fragmented and diverse, and at present it has not been positively established that health effects can be related to either short-term peak exposures or to long, but persistent, low-level exposures to any gas appliance combustion product. Findings from individual studies are contradictory, with results varying from positive (a definite cause and effect), to inconclusive (trends evident but without any statistical significance), to negative (no relationship). Thus, while no causal link has been proven, a need for more information has been established.

Studies conducted in the late 1970's in Great Britain reported that certain groups of children in homes with unvented gas appliances had more incidences of respiratory disease than children in homes with electric appliances. A recent study conducted by the Harvard School of Public Health indicated an association between NO_2 and adverse health effects but noted that this association was not statistically significant. Two studies conducted by Battelle-Columbus Laboratories in the early 1970's, with support from the American Gas Association (A.G.A.), found no relationship between exposure to NO_2 and adverse health effects. Other studies are now in progress.

Conservation Effects

The increased interest in and concern about indoor air pollution has been brought about to a large degree by nationwide efforts to conserve energy through weatherization of buildings. These efforts include installation of storm windows and doors, vent dampers, caulking, and weatherstripping—all of which impede the indoor-outdoor air exchange, or air infiltration rate.

The concern is based on the assumption that when you confine heat in a structure to conserve energy you also confine the indoor air. Certain substances and emissions that are harmless in small concentrations may become harmful as concentrations rise. Ironically, the desire for conservation may inadvertently permit the creation of a potentially harmful environment.

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Of course, there are many variables to this assumption, such as wind intensity, number and use of windows, entry and exit patterns, use of heating and cooling systems to control structure temperature, and overall tightness of construction.

Another difficulty encountered in the study of indoor air quality is that new pollutant sources are being "discovered" almost daily. Some are easily identified and can be remedied or removed through proper ventilation, such as odors from solvents and cleaning fluids. Other pollutants are more persistent and at times are found within the construction materials and the building site itself. One such pollutant is "asbestos," a collective term for various minerals in fibrous form. Asbestos has desirable thermal and electrical insulating properties which have led to its widespread use in public buildings. However, it tends to slowly disintegrate, releasing respirable fibers into the air. Research is underway to determine the effects these fibers may have on the health of building occupants.

The Consumer Product Safety Commission (CPSC) has found formaldehyde (HCHO) to be an irritant and potential carcinogen. HCHO, a chemical component of plywood, particle board, and urea formaldehyde foam insulation, "outgasses" or is emitted from these building materials for varying periods of time. These materials are extensively used in the construction of mobile homes, and high concentrations of HCHO have been measured within such structures. Because of this, the CPSC has recommended that urea formaldehyde foam be banned as a home insulating material.

Radon, another persistent problem, is a product of radium decay and is present in soil and rock. It outgasses continuously and decays into other radioactive elements which attach to respirable particulate matter in the air. Radon and its progeny also emanate from rock products used in construction, such as brick, concrete, tile, and concrete blocks. It is known that radon causes lung cancer and that radon concentrations are higher indoors than outdoors, but the exact cause and effect relationship is unknown and difficult to quantify. Control measures for radon may be required without a complete knowledge of its dose/response relationship.

Household Activities

Not only is normal household activity the major source of pollutants in indoor air, but virtually all contaminants found indoors are emitted by more than one source. Occupant activity is a source of particulate matter (dusting, cooking, vacuuming, smoking), organic compounds (cleaning products, painting), allergens (house dust, animal dander), and carbon dioxide (CO_2) from metabolic processes. Indoor activity is extremely difficult to quantify because it depends almost totally on individual patterns and habits.

To date, the most widely studied of all these activities is the smoking of tobacco. The constituents of particulate matter emitted by tobacco smoke are well known and are potentially hazardous not only to the smokers themselves but to nearby non-smokers as well. In almost all cases, particulate levels indoors have been found to be 50% higher than particulate levels outdoors. However, in a 1980 study conducted for the Electric Power Research Institute by Geomet, Inc., houses with smokers had an astonishing 300% higher concentration of particulates.

Incomplete combustion of wood or coal in devices used for heating or cooking can produce an organic particulate called Benzo- α -pyrene (B α P) which is a known carcinogen. Studies have shown that this carcinogen is emitted when these devices are not properly used. As an economical source of heat, unvented kerosene heaters have also become popular. Emissions from the unvented heaters can produce excessive levels of NO_2, CO_2, and sulfur dioxide. Product improvement and increased ventilation appear to be the ob-

vious means of controlling emissions from wood and kerosene heaters.

Also to be considered is the impact of outdoor air pollution on indoor air quality. Outdoor air pollution must be monitored adjacent to the residence sampled, and measurement is complicated by the variation of infiltration rates in residences—normally from 0.8 to 1.2 complete changes of air per hour in older homes but as low as 0.2 in homes where significant conservation measures have been taken.

A New Approach

As the debate continues against a background of a growing but still incomplete base of information, concern for indoor air quality and related health effects is increasing among representatives of the regulatory, scientific, consumer, and industrial communities. At issue is whether energy conservation requirements bring indoor air pollutant concentrations from minimal, innocuous levels, to levels that may cause adverse health effects. To date, no comprehensive study has examined the emission/health effect issue in terms of "tightening" of homes. But GRI has begun such a program, building upon the data base established by A.G.A. in the early 1970's.

To better understand the relationship between air infiltration and indoor concentrations of pollutants, GRI funded Arthur D. Little, Inc., to conduct a comprehensive survey of existing information on this subject. Published in 1981, the resulting report, titled "Potential Health Effects of Residential Energy Conservation

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Measures," estimated that indoor NO_2 concentrations (under steady-state conditions) could increase by 162% if the ventilation rate was decreased from 1.2 air changes per hour to 0.2 changes. CO concentrations under similar circumstances could increase by as much as 600%. Related laboratory experiments conducted by the Lawrence Berkeley Laboratory have shown an increase in the range of 200 to 300% for NO_2 when the ventilation was reduced from 1.0 to 0.24 air changes. CO levels increased in the range of 80 to 222% under similar conditions.

Very few data are available on the effects of "tightening" a structure but, as noted here, the wide variation in numbers clearly indicates that more research is needed to understand the air infiltration and indoor air pollution relationship. The relation between immediate consumer energy savings versus long-term potential health hazards due to loss in indoor air quality also must be closely examined. GRI's comprehensive program for indoor air quality includes such studies.

In the overall picture, GRI is naturally most interested in the factors introduced by the combustion of natural gas. Based on the A.G.A. studies of the early 1970's and on the conclusions of the Arthur D. Little study, GRI believes that in structures with normal ventilation rates, emissions from unvented gas appliances do not cause any undesirable effects. Whether or not pollutants emitted by unvented gas appliances provide a cause for concern in highly weatherized residences will be determined by the GRI-sponsored indoor air quality research program. Should this be indicated, the segment of the GRI study devoted to the development of emission controls will be stepped up to help ensure a continuing healthy environment for all residential gas users.■

As Assistant Director of Environmental Research at GRI, Dr. Donald O. Johnson oversees a program that plans, coordinates, and manages environmental research relating to utilization, supply, and distribution technologies. The study of indoor air quality is a large part of this program. Dr. Johnson received a B.S. and M.S. in Geology from Northern Illinois University and a Ph.D. in Geology from the University of Illinois.

Dr. F. Richard Kurzynske is Manager of Environmental Assessment and Control, Utilization, at GRI. This area of environmental research encompasses all gas combustion and utilization technologies as well as industrial emissions control. The GRI indoor air quality studies are managed by Dr. Kurzynske. He holds a B.A. from Andrews University and an M.S. in Environmental Engineering and a Ph.D. in Civil Engineering from the University of Tennessee.

A Comprehensive Response

In order to gain more definitive data on indoor air quality and health effects than now exist, GRI has formulated a comprehensive research program with three interrelated components.

The first component will characterize indoor emissions. The goals are to define precisely the source strengths of potential contaminants from unvented gas appliances under a wide range of operating conditions and different air exchange rates and to place these emissions into relative perspective with other significant indoor sources of contaminants. Research tasks include studying emission concentrations, examining the fates of combustion products, and identifying any secondary product contaminants. Data will be collected under controlled conditions in a specially built, all-aluminum environmental chamber with dimensions of 12 by 10 by 8 feet. Emission rates and concentrations will be measured as a function of time and distance from the source. Emission sources will include unvented gas appliances (ranges, space heaters, and gas dryers), wood burning devices, kerosene heaters, cigarette smoking, and foods being cooked.

The second component of the GRI indoor air quality study is concerned with a person's total exposure to specific emissions throughout the day both indoors and outdoors. Field measurements will record the exposure of selected segments of representative populations to various emissions for a fixed time period during their daily activities. Personal, portable, and fixed-monitors will determine exposure levels at work and at home, in transit, during recreation, and at rest. In this way, the contribution of unvented gas appliance emissions to a person's total emission exposure can be determined.

The third component of the GRI indoor air quality program is involved in developing emission controls that enhance indoor air quality. Two types of controls will be considered: multiple-source control technologies that reduce indoor contaminant levels irrespective of source (air filtration and ventilation systems) and source-specific control technologies, if needed, for gas appliances. GRI is taking the utmost precaution to ensure that any indoor air problem that may be created by the "tightening" of homes and potentially exacerbated by gas appliance emissions be resolved immediately upon identification.

A panel of nationally recognized experts has been assembled to assist in the design of GRI's indoor air quality program and to review the program's technical progress. This panel will serve to provide quality control and scientific objectivity.

The interactions among the three components of the study and input from the GRI Advisory Bodies make the GRI program a uniquely comprehensive study that will thoroughly address the environmental issue of indoor air quality.