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16. Abstract (Limit: 200 words) In response to a request from NIOSH, an extensive literature search was conducted to determine the substantive literature available on the subject of personal gas warning systems. It was decided that such a system should be compact, fully portable, and able to give warning in time for a person to escape injury. Not only was a search made of the open literature, but sources such as manufacturers' catalogues and advertisements were also searched and contact was made with six manufacturers and three organizations whose prime interests were in this field. The results indicated that very little work has been done on the development of such devices. Work was reported concerning detection of carbon-monoxide (630080) (CO), hydrazine (302012), and oxygen (7782447) levels. The total number of devices either currently available or in the experimental stage include four CO badges, one CO indicator card, one colorimetric dosimeter badge for hydrazine and other volatiles, and a cigar shaped oxygen detector. No success was achieved in finding statistics on industrial injuries caused by exposures to toxic or otherwise harmful gases. A description was offered of the personal gas detectors which were commercially available, including the names of the manufacturers and distributors. A list of gases most commonly found at industrial work sites was included along with their threshold limit values. The physiological effects of noxious gases and vapors were briefly considered.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms Personal-protective-equipment, Gas-detectors, Toxic-gases, Organic-vapors, Confined-spaces, Safety-equipment, Air-contamination, Warning-systems

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INSTITUTE OF GAS TECHNOLOGY
IIT CENTER
CHICAGO, ILLINOIS 60616

PERSONAL GAS WARNING SYSTEMS

by
J.A. Chisholm
E. Mann
D.V. Kniebes

Final Report
Project T-809
for
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
HEALTH SERVICES AND MENTAL HEALTH ADMINISTRATION
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

January 1973

SUMMARY

A literature review was carried out for the National Institute for Occupational Safety and Health on the subject of personal gas warning systems. The objectives of this review along with direct contacts with selected organisations and manufacturers were to 1) establish the state of the art of this type of warning system, 2) identify the gases that present the greatest industrial hazards, and 3) recommend the most productive areas of research to meet demonstrated occupational health needs for personal gas warning systems.

An extensive literature search revealed that very little information has been published on personal gas detectors and that most of what exists is in the popular rather than the technical literature. The existence of four carbon monoxide indicator badges, one carbon monoxide indicator card, a colorimetric dosimeter badge for hydrazine, and a pocket-sized oxygen concentration detector was established. Of these, only the carbon monxide indicators are commercially available, and their performances are unsatisfactory according to evaluations reported in the literature.

Attempts to find statistics on the frequency and nature of industrial accidents involving hazardous gases or vapors were unsuccessful. Although information of this type has not been accumulated to date, it will in the future. Therefore, it will be several years before sufficient data are available to permit identification of the most frequently encountered hazardous gaseous agents.

Although statistical data are not available, several hazardous atmospheres are known to be frequent causes of accidents involving personnel. These consist of carbon monoxide and combustible-gas-containing atmospheres, and simple asphyxiating atmospheres due to the lack of oxygen. Other commonly encountered hazards are atmospheres containing lead and mercury. The development of devices suitable as personal gas warning systems is considered feasible for these situations. It is our recommendation that initial research efforts be directed toward these systems.

It is of equal importance to ensure that in the future an organized effort is maintained to collect industrial injury data and identify any gaseous agents involved. This information should then be used to set priorities for the development of new personal gas warning systems.

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I. INTRODUCTION

This report is in response to a request from the National Institute for Occupational Safety and Health for a review of the literature on the subject of personal gas warning systems and an evaluation of this information with a view toward future research needs. A study was thereby carried out with the following objectives.

- The establishment of the present state of the art for personal gas warning devices
- The identification of gases and vapors that present the greatest hazards to personnel in occupational environments
- The recommendation of the most productive areas of research to meet actual needs for inexpensive personal gas warning devices

II. LITERATURE REVIEW

A. Definition of a Personal Gas Warning System

A personal gas warning system should be a device with the qualities of being compact, fully portable, able to give warning in time to prevent personal injury, easy to maintain, and relatively inexpensive. In the scope of this study "compact" and "portable" mean being small enough to be held in the palm of the hand and weighing several ounces or less. The device could be a badge similar to the familiar film badge for ionizing radiation, which could be clipped or pinned to an individual's clothing. It might also be a small unit that could be carried in the shirt pocket. Upon exposure to significant concentrations of a gas or vapor, an alarm such as an audible tone signal, color change, meter reading, or blinking light could indicate a warning. In the case of color change, color standards would be read directly from the badge, providing a quick indication of concentration.

B. Results

An extensive search of the literature, manufacturers' catalogs, and advertising was conducted, and six manufacturers and three organizations whose interests are pertinent to the topic under study were contacted directly. A listing of these sources is presented in the Appendix.

The results of this search show that very little work has been done on the development of personal gas warning systems. The only areas in which work is reported are in carbon monoxide, hydrazine, and oxygen detection.

The total number of devices either now available or reported as experimental are four carbon monoxide indicator badges, one carbon monoxide indicator card, one colorimetric dosimeter badge for hydrazine and other volatile bases, and a cylindrical, cigar-size oxygen detector. These all meet the physical requirements for personal gas detectors. Unfortunately, the only impartial evaluation of carbon monoxide indicators gave negative performance results so at this time these devices cannot be considered adequate for applications in industrial environments. The hydrazine and oxygen detectors are not available commercially; to make them available would take further development effort.

An attempt to find statistics on industrial injuries caused by toxic or otherwise harmful gases was unsuccessful. The agencies that normally keep records of industrial accidents have not assembled information of this type, but indicated they would in the future. Thus, it may be several years before it becomes possible to identify the gaseous agents responsible for the highest incidence of injuries among industrial workers. Although there are no supporting statistics, it is possible to identify three areas of need for personal gas warning systems: the detection of carbon monoxide, combustible gas-air mixtures, and oxygen-deficient air. Since incidents involving these hazards are reported with sufficient frequency to warrant concern, efforts to develop practical personal gas warning systems should give priority to these items.

1. Personal Gas Detection Devices

The following carbon monoxide detectors have been established as being commercially available:

a. Carbon Monoxide Dark Spot Indicator Badge

Manufactured by:	Special-Laboratoriet Risskov, Denmark
Distributed by:	Ward International, Inc. Granada Hills, California 91344

This badge is a plastic triangular tab, about 2-1/2 inches on a side, on which is mounted a small disk of tan-colored material. The manufacturer claims that it will start to change from a light-cream color to various shades of grey at a CO concentration of 200 ppm. (A more sensitive model with a detection limit of 50 ppm is said to be under development.) The manufacturer would offer no details on the chemical reaction involved.

The badge was evaluated by the March 1972 Consumer Reports[1] The magazine says this unit is intended primarily for use in passenger automobiles, and sells for about $1.00. In the opinion of this article, the device is not effective. The badge is enclosed in sealed plastic. An effective life of 1 year is claimed for the sealed package. When the badge is exposed to air, its life is supposed to decrease to 3 months. It is also claimed to be effective for hydrogen sulfide.

The chemical reaction involved may be similar to that of the Drager and Bureau of Mines CO detection tubes: the reduction of ammonium molybdate to molybdenum blue by CO under the catalytic effect of $PdCl_2$. Another possible reaction is the reaction of CO with iodine pentoxide, which liberates free iodine.

b. Detector Corp. Carbon Monoxide Indicator

Manufactured in: Denmark

Distributed by: American Carbon Monoxide Detector Corp.
Coral Gables, Florida

This is an off-white plastic tab containing a small disk, about 2 inches square. It appears to be a copy of the Dark Spot Indicator Badge. Consumer Reports indicates it is ineffective at a concentration of 100 ppm.

c. Carbon Monoxide Detector – DEAD STOP[2]

Sold by: J. C. Whitney
Chicago, Illinois

This appears to be a copy of the Detector CO Indicator (b above)

d. CO Detector – No Monox

Manufactured by: Harvey-Westburg Corporation
Westburg, New York

This appears to be a copy of items (b) and (c) above. This is discussed in a short article found in the November 1972 Popular Science[3]

e. Carbon Monoxide Indicator Card

Manufactured by: Tomorrow's Products
Crystal Lake, Illinois

This is a piece of cardboard, 2 inches by 5 inches, across the bottom of which is an indicator strip that is about 1/4 inch wide. Above the indicator strip is a color-scale indicator, ranging from light yellow to black. The indicator strip on the cardboard is dipped into water and allowed to soak for 30 seconds, then the cardboard is placed in the area to be monitored. The strip should darken within 5 minutes in the presence of CO.

No information is available on the sensitivity claimed. It is also supposedly effective for hydrogen sulfide. This does not appear to be suitable for industrial occupational environments because it has to be moistened to be effective.

The oxygen and hydrazine detectors not available commercially are —

f. Oxygen Detector[7]

Developed by: Institute of Gas Technology
Chicago, Illinois

This is a metal,cigar-sized cylindrical tube that may be preset to respond to a specific concentration of oxygen in the environment. It is a battery-operated unit on which a flashing light indicates whether the preset concentration is being maintained. When the light stays on, the concentration is above that preset concentration; when the light goes off, the concentration is below the preset value.

The tube is quite dependable, small enough to fit in a shirt pocket, inexpensive, and apparently meets all the needs of a personal gas warning device for oxygen.

g. Colorimetric Personal Dosimeter for Hydrazine Fuel Handlers

Developed by: Mine Safety Appliances
Pittsburgh, Pennsylvania

When this badge is exposed to hydrazine or other volatile bases, it develops a color. This detector was reported in abstracts of the American Industrial Hygiene Conference in Chicago in 1967.[9]

2. Hazardous Gases Found in Industry

Table 1 is a list of the gases most commonly found at industrial work sites.[8] The threshold limit values* were obtained from Documentation of Threshold Limit Values for Substances in Workroom Air, published by the

* The threshold limit value (TLV) is generally defined as that concentration to which the average worker may be continuously exposed 8 hr/day, 5 day/week without harmful effect.

Table 1. MOST COMMONLY FOUND GASES AT INDUSTRIAL WORK SITES

		TLV
Inorganic		
	Sulfur Containing	
	Hydrogen Sulfide †*	10 ppm
	Sulfur Dioxide †*	5 ppm
	Nitrogen Containing	
	Ammonia †	25 ppm
	Hydrazine	1 ppm
	Nitrogen Dioxide †*	5 ppm
	Carbon Containing	
	Carbon Monoxide †*	50 ppm
	Carbon Dioxide	5000 ppm
	Carbon Oxysulfide	None given, highly toxic and odorless
	Nickel Carbonyl †	0.001 ppm
	Halogens	
	Fluorine †	0.1 ppm
	Hydrofluoric Acid †	3 ppm
	Chlorine †	1 ppm
	Hydrochloric Acid	5 ppm
	Bromine	0.1 ppm
	Phosgene †*	0.1 ppm
	Arsenic Containing	
	Arsine †*	0.05 ppm
	Metals	
	Lead †	0.2 mg/cu m
	Mercury †	0.05 mg/cu m
Organic		
	Hydrocyanic Acid †*	10 ppm
	Carbon Disulfide †*	20 ppm
	Aliphatic Chlorinated Hydrocarbons †*	
	Methyl Chloride	100 ppm
	Ethylene Dichloride	50 ppm
	Chloroform	50 ppm
	Carbon Tetrachloride	10 ppm
	Acetone	1000 ppm
	Aldehydes	
	Formaldehyde	2 ppm
	Acetaldehyde	100 ppm
	Acrolein	0.1 ppm
	Furfural	5 ppm
	Ethylene Oxide	50 ppm, no serious injuries reported
	Epichlorohydrin	5 ppm, no serious injuries reported
	Acrylonitrile	20 ppm
	Aromatic Hydrocarbons	
	Benzene *	25 ppm
	Toluene	200 ppm
	Xylene	100 ppm
	Phenol †	5 ppm
	Benzidine	None given. Contact by any route should be avoided because of the high incidence of bladder tumors among workers exposed to this chemical.
	Aniline *	5 ppm
	Nitrobenzene	1 ppm

*Mentioned by British Factory Inspectorate as being the more important gases found in industrial work sites[5]

† Mentioned by Hunter as being important in organic diseases[6]

American Conference of Governmental Industrial Hygienists in 1971[4] These gases should be given the highest priorities in the development of warning systems.

Hydrogen and methane are other important hazardous gases because of their explosive properties.

The effects of noxious gases and vapors are best classified on a physiological basis. They include simple asphyxiants, chemical asphyxiants, irritant gases, organo-metallic gases, and anaesthetic vapors.

a. Simple Asphyxiants

Gases like nitrogen, methane, and hydrogen may cause death from simple asphyxia through deprivation of oxygen.

b. Chemical Asphyxiants

Commonly encountered chemical asphyxiants are carbon monoxide, hydrogen sulfide, and hydrogen cyanide. Hydrogen sulfide may be considered self-warning because of its characteristic odor.

c. Irritant Gases

Some of the irritant gases are sulfur dioxide, ammonia, nitrous fumes, chlorine, fluorine, and hydrogen fluoride. Certain of these gases are physiologically impossible to breath in any but very low concentrations,so they may be considered self-warning.

d. Organo-Metallic Gases

Gases such as nickel carbonyl and arsine are hazardous. Nickel carbonyl is one of the few industrial posions that may kill outright.

e. Anaesthetic Vapors

Benzene and carbon tetrachloride are anaesthetic-type vapors.

C. Discussion

Considering the scarcity of previous work and the present availability of personal gas warning systems leads to the conclusion that either the demand for such systems has been minimal or that technology has not existed to develop practical devices. We feel that the first factor has predominated. In an industrial situation where the threat of hazardous atmospheres exists, a central air-monitoring device is usually used to give warning to personnel in the vicinity. This type of protection normally obviates the need for a device worn by the individual worker. In those special situations where area monitors cannot be used effectively, the lack of available personal warning devices has probably been due to the technical difficulties of producing a reliable but inexpensive device. Most of the technical difficulties can be overcome with sufficient research effort, but the market for such devices has not been large enough to attract the required funding. It is highly probable that research and development efforts of modest scale can produce a variety of practical personal gas warning systems to meet the needs of industry. However, individual companies will, in general, not find the market worth the necessary investment. This, of course, could change if regulations were to be put into effect requiring increased protective measures for workers who might be exposed to hazardous atmospheres.

The establishment of criteria for the performance of personal gas warning systems should be a straightforward effort if threshold limit values for a given gas have been established. This has been done for most materials of concern. The required sensitivity of the system can thus be determined, and other criteria such as size, weight, shelf life, measurement accuracy, operating time without service, and type of warning signal can be established for each gas or vapor of interest. Response time, for example, must be rapid with certain gases such as carbon monoxide that represent an immediate threat, whereas exposure of a worker to low levels of a cumulative poison such as lead or mercury compounds could be detected by a chemical system that would be processed and read periodically much like a nuclear radiation badge.

III. RECOMMENDATIONS

Efforts should be made through established organizations to gather industrial injury data involving gaseous materials. In this way, the most important needs for personal gas warning systems can be identified. Until such data can be obtained, it is recommended that efforts be directed toward the development of devices that give prompt warning of hazardous concentrations of carbon monoxide and combustible vapors, and of the lack of sufficient concentrations of oxygen for breathing. All of these devices now exist in a form too bulky for personal use; thus satisfactory devices could probably be developed with modest development effort.

A study should also be made to establish those commonly encountered gases that are hazardous only over long exposure periods. Warning devices for these agents could consist of relatively simple chemical systems that would integrate exposures and provide a dosage measurement at periodic reading intervals. Many chemical reactions are potentially available for this type of application.

In summary, of the many harmful gaseous materials that a worker may contact, a large number are self-warning, either by a distinct odor or by another physiological affect. The remaining can be divided into two groups, fact-acting gases such as carbon monoxide, or slow-acting vapors such as lead and mercury compounds. Standards for personal warning devices should be somewhat different for each group. Other hazardous atmospheres can be broadly classed into two other groups, both nontoxic. One group consists of combustible or explosive atmospheres, and the other, of simple asphyxiants that cause harm by excluding oxygen. Both types of atmospheres would require fast-response warning devices. The outlook for developing useful personal warning systems is good with today's technology. An organized effort in this direction should be very productive over a time span of 1-5 years.

IV. REFERENCES CITED

1. "A Do-It-Yourself Test for Carbon Monoxide?" Consum. Rep. 37, 133-35 (1972) March.

2. "Carbon Monoxide Detector," J.C. Whitney Catalog No. 300. Chicago, 1972.

3. "CO Detector," Pop. Sci. 201, 110 (1972) November.

4. Documentation of Threshold Limit Values for Substances in Workroom Air, 3rd Ed. Cincinnati: American Conference of Governmental Industrial Hygienists, 1971.

5. Great Britain Ministry of Labour, British Factory Inspectorate Leaflets.

6. Hunter, D., The Diseases of Occupations, 4th Ed. Boston: Little, Brown, 1969.

7. Klass, D.L., "IGT's In-House Research Program, 1970, Annual Summary Report." Chicago: Institute of Gas Technology, 1971.

8. Leithe, W., The Analysis of Air Pollutants. Ann Arbor, Mich.: Ann Arbor Science Publishers, 1971.

9. Plantz, C.A., McConnaughey, P.W. and Jenca, C.C., "Colorimetric Personal Dosimeter for Hydrazine Fuel Handlers," Am. Ind. Hyg. Conf. Abst., 111 (1967).

APPENDIX. List of Source Material

The following publications were searched to help determine the state of the art concerning the existence of personal gas warning devices for toxic or dangerous gases encountered in industrial environments.

Abstracts and Indexes Searched

Applied Science and Technology

American Industrial Hygiene Abstracts, Conference

Bureau of Mines Publications

Engineering Index

Medicus Index

Reader's Guide to Periodical Literature

Specific Journals Reviewed

Air Pollution Control Association Journal

Archives of Environmental Health

Pollution Abstracts

Pollution Equipment News

Thomas Register

Other Publications

"A Do-It-Yourself Test for Carbon Monoxide?" Consum. Rep. 37, 133-35 (1972) March.

Documentation of Threshold Limit Values for Substances in Workroom Air, 3rd Ed. Cincinnati: American Conference of Governmental Industrial Hygienists, 1971.

Great Britain Ministry of Labour, British Factory Inspectorate Leaflets.

Hunter, D., The Diseases of Occupations, 4th Ed. Boston: Little, Brown, 1969.

Leithe, W., The Analysis of Air Pollutants. Ann Arbor, Mich.: Ann Arbor Science Publishers, 1971.

Headings Checked

The following headings were checked in the publications searched.

Badges

Carbon Monoxide Detectors

Chemical Plants — Safety Measures

Detectors

Gas Analysis

Gas Detectors

Gas Hazards

Gas Indicators

Gas Monitors

Hazards — Industrial Hazards

Indicators

Monitors

Safety Devices and Measures

Warning Systems

Organizations Contacted

The following organizations were personally contacted:

American Industrial Hygiene Association,Westmont, N.J.

New Jersey Bureau of Engineering and Safety,Trenton, N.J.

National Institute for Occupational Safety and Health ,Chicago, Illinois

The following manufacturers of pollution detection instrumentation were also personally contacted and their catalogs and advertising literature reviewed:

Mine Safety Appliance Company,Pittsburg, Pa.

CEA Instruments,New York, N.Y.

Doerfer Labs,Cedar Falls, Iowa

Corning Labs,Cedar Falls, Iowa

REM, Inc.,Santa Monica, Calif.

Tomorrow's Products,Crystal Lake, Ill.

A do-it-yourself test for carbon monoxide?

When we reported on carbon monoxide in *Corvairs* last September, we commented that the owner of a *Corvair*—or any other car, for that matter—would probably have to go to some trouble to have his car tested for the presence of carbon monoxide (CO) in the passenger compartment. In our own testing of 221 *Corvairs*, we used fairly elaborate electrical test equipment operated by a trained technician.

Since then, a number of readers have written in to tell us about a couple of cheap, easy-to-use devices designed to detect and signal dangerous levels of CO. They're simply plastic tabs that hold a small disk of tan-colored material that's supposed to darken on exposure to CO.

Detector Carbon Monoxide Indicator (American Carbon Monoxide Detector Corp., Cape Coral, Fla.) is an off-white tab about two inches square; we ordered ours from J. C. Whitney & Co., Chicago, at a list of 98¢ each plus shipping. *Dark Spot = Carbon Monoxide Indicator* is a tan triangular tab that measures about 2½ inches on each side; ours came from Wards International, Granada Hills, Calif., and list at $1 each postpaid (or 50¢ each plus shipping on orders of 12 or more). Both are labeled as coming from Denmark.

As we pointed out in the *Corvair* story, scientists differ in their estimates of "permissible" degrees of exposure to CO. In general, though, they agree that the potential for trouble can begin when people are exposed to CO concentrations of 100 parts per million parts of air (ppm) for 30 to 60 minutes and of 50 ppm for more than an hour. Thus, a CO detector should start signaling at around 50 ppm, and certainly the warning should become clear when the concentration reaches 100 ppm.

We got no clear warning reactions with either the *Detector* or the *Dark Spot* when we exposed them to CO concentrations of about 100 ppm for between 30 and 90 minutes. With the *Detector*, in fact, we could detect no warning reaction at all, even though we tried seven samples at the 100-ppm concentrations. (Note, too, that with the *Detector*, a reaction may not be easy to identify since the plastic tab and the reactant disk are of different colors. A color chart, which we obtained from the manufacturer separately, supposedly enables you to read CO concentrations shown by the disk. But the color on the chart designated as "safe" wasn't the same color as the indicating disks on our unused samples.)

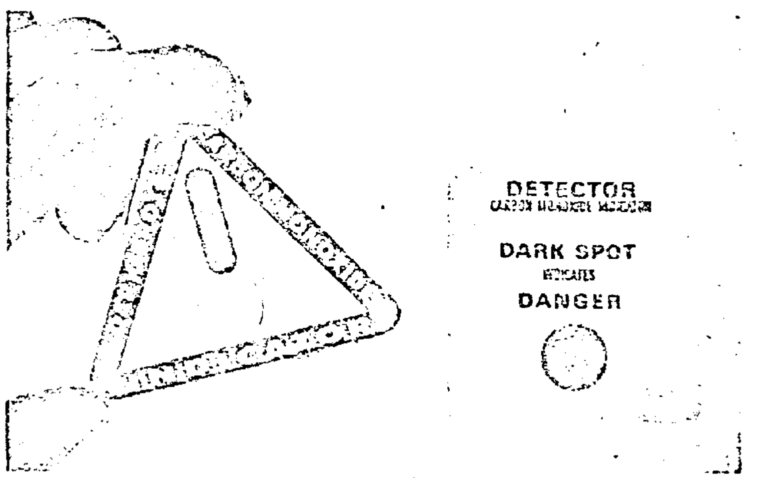
The *Dark Spot* acquitted itself slightly better. To start off with, the plastic tab and the indicator disk on a fresh sample are about the same color, so color changes are easier to notice. With samples that we exposed to CO at about 100 ppm, we were able to observe a reaction after 90 minutes, although the darkening effect was so subtle that we wonder whether the average person would perceive it in ordinary circumstances. We were making our observations in a well-lighted laboratory; visibility conditions would often not be that good in a car.

To give these products every benefit of the doubt, we exposed several samples of each to CO concentrations of about 400 ppm—a level that would probably cause very undesirable effects in most people within a relatively short time. Again, the *Detector* came off badly. Only one sample showed a definite reaction after 10 minutes. Most of the others produced uncertain reactions within 10 to 30 minutes, and one reacted not at all even after an exposure of many hours. All of the *Dark Spot* samples showed a perceptible change of color within three to 15 minutes of exposure.

CO detection is also of interest to owners of small aircraft, because malfunctioning cabin heaters of such planes can produce dangerously high CO levels. The Federal Aviation Administration has reported on detectors, including the *Detector* model we tested. The FAA report (#ADS-80) concludes, in essence, that that product would do the job it's supposed to do. CU disagrees.

It appears that the *Dark Spot* might warn you of imminently dangerous levels of carbon monoxide. But as we've pointed out, the potential for danger exists at levels much lower than those at which the *Dark Spots* showed an unmistakable reaction. As for the *Detectors*, they reacted so erratically that we wouldn't trust them to let you know if you were in serious danger, much less to tell you if the CO concentration was approaching a hazardous level.

The consumer who wants a reliable measurement of CO, one that would reveal the point at which danger begins, has a problem. Few dealerships or service stations appear to have equipment that will indicate CO concentrations of at least as low as 50 ppm (or 0.005% as it's shown on some indicators). If you can find a local facility equipped to measure such low concentrations, by all means have tests made. If you can't, be wary of any perceptible exhaust fumes in your car. Although CO is odorless, it often travels in company with exhaust gas fumes you can smell. Should you detect such fumes, have your exhaust system checked and any leaks in it traced and repaired promptly.



Fresh samples show color-matching problem. On square, right, spot is already dark, so how can you tell how dark is dark? Better is the triangle, on which spot and background are same color. However, neither warned of low, but potentially dangerous, CO concentrations.

ENVIRONMENTAL

DETECTOR

FOR

CARBON MONOXIDE

IN YOUR

AUTO • KITCHEN • BASEMENT
WHEREVER COMBUSTION OCCURS

BE ALERT...
CHECK THE AIR
YOU **BREATHE**

NORMAL DANGER

INDICATOR STRIP

CARBON MONOXIDE DETECTOR

Carbon Monoxide (CO) is a colorless, **odorless**, poisonous gas that occurs as a by-product of combustion and can exist wherever there is combustion. **When inhaled even in small quantities your health may be endangered and in concentration may cause death.**

This detector provides a simple test for the presence of carbon monoxide, and its use could save your life.

INSTRUCTIONS

Dip carbon monoxide indicator strip at bottom of card into water and allow to soak for 30 seconds. Place in area suspected to contain carbon monoxide and if strip darkens within 5 minutes of exposure at 60° F., CO is present. When discoloration reaches the caution level, (compare with scale indicator) **TAKE IMMEDIATE CORRECTIVE ACTION.**

CAUTION: Keep away from eyes and mouth after dipping into water.

This detector may also be used to test for hydrogen sulphide (sewer gas) by following the procedure above.

TOMORROW'S PRODUCTS
Crystal Lake, Illinois 60014

Carbon Monoxide Detector

Warns Against the Silent Killer

Carbon monoxide can cause drowsiness, dizziness. Darkening of spot on detector shows carbon monoxide is present. Detector can be reused, spot lightens in fresh air. Small 2"x2" disc mounts on dash or window with simple adhesive backing or with top-hole hanging.

17-7084—Shpg. wt. 1 oz. ....Each 98c

CO detector

Now you can detect odorless, deadly carbon monoxide (CO) gas in your car or home. If the pink chemical on the No-Monox turns gray to black, you know a dangerous CO level is present. Harvey-Westbury Corp., 81 Urban Ave., Westbury, N.Y. 11590.

COLORIMETRIC PERSONAL DOSIMETER FOR HYDRAZINE FUEL HANDLERS

Charles A. Plantz, Paul W. McConnaughey and Cecelia C. Jenca
Mine Safety Appliances Company
Pittsburgh, Pennsylvania

A dosimeter badge has been developed which does for hydrazine fuel handlers, what a film badge does for handlers of ionizing radiation. On exposure to vapors of hydrazines and other volatile bases the sensitive material contained in the badge develops a color whose intensity is approximately proportional to the integrated concentration-time value to which the badge has been exposed. Color standards are on the badge, so that the color and therefore the concentration-times-time of the exposure can be estimated by fuel handlers in the field. The colorimetric substance is bindone ($\Delta 1,2'$-biindan) -1', 3,3'-trione, impregnated on thin layer chromatography material.

IGT
EDUCATION · RESEARCH

IGT'S
In-House Research Program
1970
Annual Summary Report

Prepared for IGT Members,
International Associates, and Contributors

By Donald L. Klass*

Introduction

In our annual report for fiscal 1968-69, we outlined the three major objectives of IGT's in-house research program, summarized some of the technical achievements of fiscal 1969, and indicated that similar reports to keep you informed of the status of this program would be distributed annually.

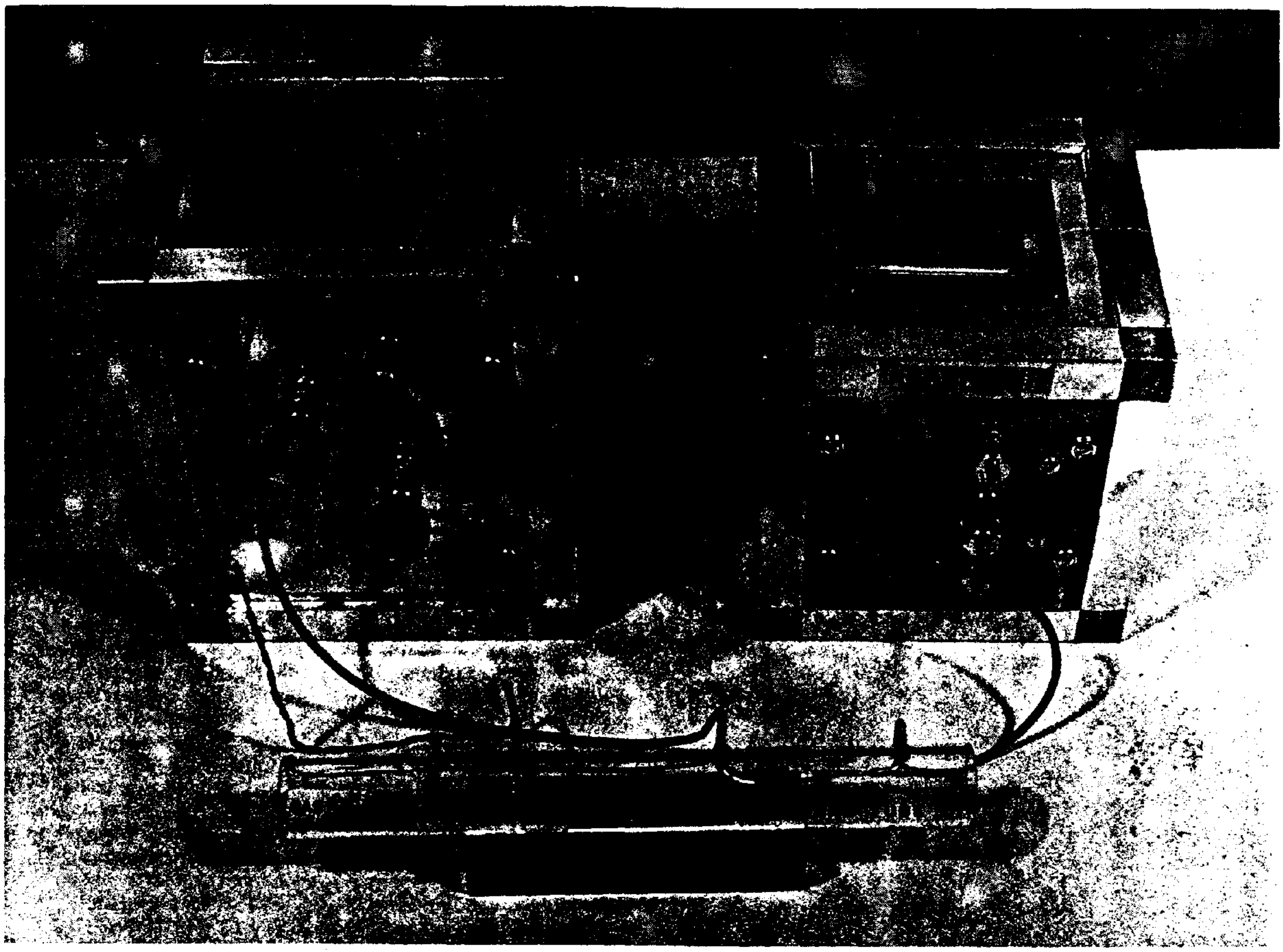
For the benefit of new Members and International Associates, let us briefly review the objectives and reasons for the in-house research program before summarizing the achievements of fiscal 1970. The three major objectives of this program are: 1) the continuous development of new knowledge and information necessary to advance gas industry technology, 2) the continuous improvement of the skills and proficiency of IGT's professional staff, and 3) the establishment of the technical or economic feasibility of new concepts worthy of financial support by prospective sponsors. The program is financed largely by Member dues, though some support comes from contributions and grants. Both professional personnel and graduate students are involved in this effort on a full- or part-time basis.

Many of IGT's presently-sponsored projects started as in-house research. Perhaps the best example of this is the coal gasification program. It is aimed at the development of a commercial process to produce pipeline-quality gas that can become a major source of supply to help meet the pending gas shortage. The initiation of this work in the 1940's as part of the in-house program illustrates how important project selection is, especially when dealing with future needs of the gas industry. In this case, what started as a few laboratory experiments developed into a timely and valuable technological advancement.

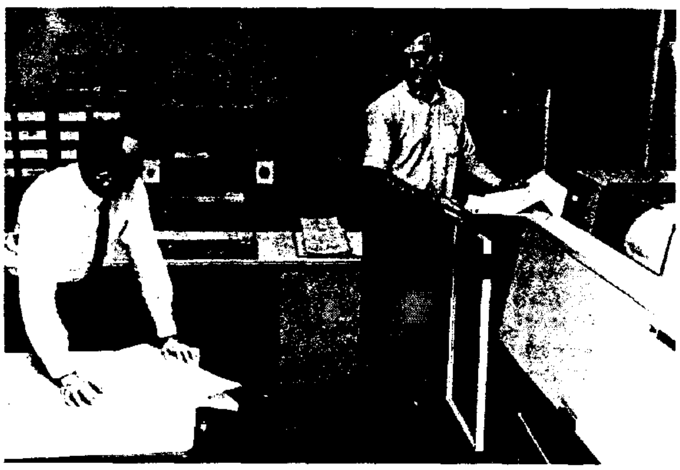
It is not easy to predict the outcome of particular research projects at the beginning of the work, nor is it easy to predict the actual value of the results. Nevertheless, the probability of success in a research program can be increased if the potential value and applications of the results are considered at an early stage in the work. This philosophy has been incorporated more strongly this year into our in-house research program. We expect that it will have an even greater impact on the gas industry in the years to come than it has in the past.

This device is a sensitive portable oxygen detector that can be pre-set to respond to a specific concentration of oxygen in the environment. It is an example of the exploratory work done at IGT to determine the technical feasibility of new concepts.

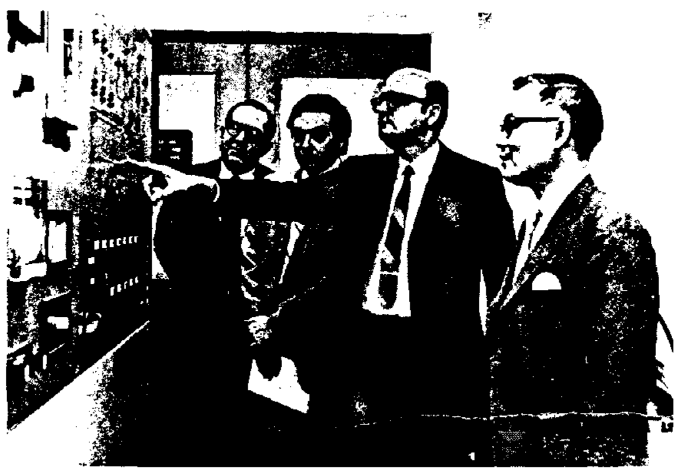
**Dr. Klass is Assistant Research Director at IGT.*



Another device that was designed, built, and tested as part of IGT's in-house research program is this small automatic odorizer. It demonstrated the feasibility of a new concept of metering precise amounts of odorant to natural gas to maintain a desired level in the distribution system.



Graduate students have direct access to this new computer installation at IGT. A large variety of gas-industry-related problems are studied and modeled with this equipment. For example, the computer program for the calculation of equilibrium yields and distributions of 200 simultaneously-formed compounds generated at elevated temperatures and pressures was perfected with this equipment. It would be virtually impossible to obtain this information by hand calculations.



IGT's Klass points out features of pilot plant fermentation control panel for Northern Illinois Gas Company personnel. This plant is used for the production of high-protein vitamin-rich foodstuffs from natural gas. The original work on the process began in the laboratory as an IGT-supported research project, and is now sponsored by NI-Gas.

In fiscal 1970, the in-house research program continued with emphasis on those concepts and ideas that would attract the additional financial support needed to develop them into useful products and processes. Clearly, the most difficult hurdle to overcome in conducting this kind of program is not the conception of the new idea itself; it is the conception of a new idea that will either fulfill an existing or future need of the gas industry, or that will open the way to new applications, and hence new markets, for natural gas. In these days of inflation, tight money, and an ever-decreasing return on R&D investment dollars, it is not possible for the scientist or engineer to sit isolated in an ivory tower and meditate over the aesthetic value of a particular observation or result. Barring true technological breakthroughs, which are becoming increasingly rare, research to develop knowledge for knowledge sake alone is the most unprofitable pursuit one can undertake. A fine piece of research is worthless if the results are never used to benefit man and his environment. We are therefore constantly on the alert to apply the information accumulated in our research to the real world.

In line with this thinking, most of the projects making up the 1969-70 program were directed to the solution of specific gas industry problems in the areas of supply, distribution, and utilization.

For those of you who are interested in the subjects studied in fiscal 1970, a complete list of project titles is included in this report. For more information on a specific project, please contact me at IGT.

In the release of information on specific projects, IGT observes certain guidelines to provide maximum benefit to the gas industry. The usual practice is to operate within the constraints of patent law which may restrict the publication of concepts on which patent applications are pending. Details of other projects which have not resulted in patentable inventions are published and are freely available. This is reflected in the numerous papers and presentations that are periodically mailed to IGT's Members, International Associates, and Contributors. For some projects that have patentable concepts worthy of further financial support, IGT seeks interested sponsors to ensure the continued effort needed to achieve commercialization. In such cases, the sponsor often acquires rights similar to those presently offered by IGT on its sponsored projects.

1969-1970 PROGRAM

Some of the technical achievements of the fiscal 1970 program are summarized below.

■ A program was perfected and used for computing the equilibrium concentrations of 200 compounds formed simultaneously from any number of reactants. The methane-ammonia-water system was studied to ascertain the effect of broad ranges of temperature, pressure, and reactant ratio on the equilibrium yields and product distributions. This program is quite useful for computing equilibrium yields of simultaneous reactions because it is not necessary to specify the chemical reactions that occur in the system. It is of great value to optimize yields of desired products in many multi-product processes.

■ A new method was conceived for the odorization of natural gas. This method is believed to be suitable for unattended operation in both large and small odorizing installations. It has been demonstrated in the laboratory by construction of a small odorizer equipped with a feed-back system that meters precise amounts of odorant as a function of gas flowrate.

■ A novel oxygen-sensing device was built to demonstrate the technical feasibility of a new concept of designing inexpensive portable gas monitors. Quantitative or qualitative sensing of oxygen can be performed with this system. Applications envisaged for the system include oxygen sensing in subterranean and elevated locations. The principles of its operation are expected to be applicable to the detection of other gases.

■ New rate constant data were determined for the ethylene-hydrogen atom reaction in a specially designed fast-flow gas-phase reactor coupled to a time-of-flight mass spectrometer. This unique facility permits studies of the elementary reaction steps and reactive intermediates that occur when gas ignites.

■ The permeation characteristics of methane-hydrogen mixtures were studied with selected membranes. Certain membranes were found to exhibit high selectivity for hydrogen permeability, and may offer a means of designing a practical gas purification system.

■ An improved process was conceived for the electrochemical production of aluminum using natural gas as a source of hydrogen. Unlike present commercial processes, which have been used in essentially the same form for the last 75 years, this new process does not consume the anode. Preliminary experimental work has established the technical feasibility of the process.

■ A specially-designed compact reactor was built to reform methanol. Low-temperature acidic fuel cells were successfully operated using the total effluent from the methanol reformer as the fuel, and air as the oxidant. Some carbon monoxide poisoning effects were observed, but further development of the reformer is expected to minimize or eliminate this problem.

■ Exploratory studies were started on the use of supersonic fog flows in cooling applications. The initial work was the design and construction of a supersonic fog flow generator. Tests indicated that uniform flows can be achieved. The ultimate objective of this work is to develop compact large-tonnage gas-fired cooling devices that have few moving parts.

■ Experimental data for the carbon dioxide-potassium carbonate gas-solids reaction were compiled. This data shows that the system can be used for the effective removal of carbon dioxide from gas streams that contain carbon dioxide in the 1% range. The active solid can be regenerated by simple heating.

■ An analytical solution for gas distribution in fuel cells equipped with internal distributors was derived.

■ Economic studies were conducted on the feasibility of two IGT-conceived desalination processes. One concept used a liquid heat exchanger and the other used a solid-liquid phase change to remove the heat of hydration of water in brines. The energy is conserved and then used to decompose the hydrate to form desalted water. The studies showed that these methods are not competitive with the best desalination processes known today.

■ A new process was conceived to suppress and eliminate nitrogen oxides. It involves thermally regenerative separation and decomposition. This technology is expected to be applied in pollution control systems for both stationary and mobile sources of nitrogen oxides.

■ A new technique was developed for the assembly and testing of electrodes for use in high-temperature alkali metal batteries. The technique consists of immobilizing the electrode materials by impregnating them into a porous electrically-conductive support in a specially designed dry box. The solidified electrodes allow convenient assembly of test cells at room temperature.

■ Improved methods were developed to determine tracer distributions in tapered fluidized bed reactors. The differential equations that represent the mixing characteristics in such reactors were solved by means of Laplace Transforms, and a method for estimating mass transfer coefficients in the fluidized bed was developed.

■ Electrochemical and mass transfer studies of biologically implantable fuel cells that can be used to power artificial hearts showed that such systems are within our present technical capabilities.

■ A vapor-liquid equilibria apparatus was constructed which permits accurate compositional data to be determined for LNG over a wide range of pressure and temperature.

■ A novel method of odorizing liquefied hydrocarbons that are normally gaseous at room temperature was conceived to eliminate the odor fading that often occurs when the hydrocarbon is vaporized. This method may be able to maintain the odorization level of cryogenic liquids such as LNG and LPG.

■ A study was conducted on methods of selecting the optimum site for a coal gasification plant in terms of minimum transportation costs. It was concluded that for a single mine and water source, the optimum location can be evaluated by considering four sites: at the coal mine, at the water supply, on the pipeline at a position closest to the mine, and on the pipeline at a position closest to the water supply.

■ Viscosity measurements were completed on several methane-*n*-hexadecane mixtures near the bubble point regime where only limited information is available. Such data are required for predicting the viscosity characteristics of hydrocarbon mixtures in petroleum reservoirs. This work was partially supported by a grant from the American Petroleum Institute.

■ Equations were derived to describe film formation rates for regenerative reactors that use the melting and freezing of a material for producing the heat regenerative action. Other equations were developed to relate film formation rates to equipment design parameters.

■ Studies have continued on the relationship of the optical properties of low rank coals and their pore characteristics. This work employs microscopic reflectance techniques. It may lead to improved methods of characterizing low-rank coals for hydrogasification applications.

■ The residence time distribution technique was used to show that there is no stagnant "dead" space in the IGT molten carbonate fuel cell flow chambers. The results indicate that the cell-baffling design substantially improves flow performance over that of a non-baffled chamber.

■ Experimental studies have led to a better understanding of the rate determining processes involved in the adsorption of oxygen on platinum electrodes. This information will be useful in the further development of fuel cells and in various heterogeneously catalyzed processes using oxygen and air.

■ A new mathematical model for gas-solid reactions was developed. Unlike previous models, it treats the plugging of the pores of the solid reactant.

■ A least squares procedure to adjust dew and bubble point data was developed and applied to the available data for methane-nitrogen mixtures.

■ Experimental studies of the retorting of oil shale have shown that the presence of hydrogen offers little or no advantage over conventional retorting conditions for the production of liquid hydrocarbons.

IN-HOUSE RESEARCH CONDUCTED BY THE IGT STAFF IN FISCAL 1969-70

Application of Management Science to Gas Industry Business Decisions
Cathodic Reduction of Aluminum Using Hydrogen Derived From Natural Gas
Construction of a New Vapor-Liquid Equilibria Apparatus
Construction of Precision Odorizer Demonstration Apparatus
Construction of Pulse Flow Gas Calorimeter
Construction of 3-Ton Munters Environmental Control Unit
Development of a High-Energy Battery
Development of Novel Range Concepts
Direct Energy Conversion for Cardiac Pace-Maker Power
Dynamic Evaporator
Economic Analysis of Combination Heat-Light Devices
Economic Analysis of Novel Desalination Processes
Economic Analysis of Oxygen-Based Coal Gasification Processes
Economic Analysis of Peakshaving With LNG
Electrochemical Studies of Oxygen Adsorbed on Platinum
Elementary Gas Phase Kinetics
Fuel Cell-Storage Battery Hybrid Systems
Gas Distribution and Operating Model
Heat and Mass Transfer in Fuel Cells
Improved Methanation Catalysts
Infrared Detection of Natural Gas Leakage
Kinetic Studies of Natural Gas Reforming for Low-Temperature Fuel Cells
Mechanism of Microbial Oxidation of Methane
New Concepts of Fuel Cells
Numerical Methods in Transport Phenomena
Organization of Appliance Statistics
Production of Useful Products From Refuse
Reflectance of Low-Rank Coals
Regenerative Sorption of Carbon Dioxide
Residence-Time Distribution and Chemical Engineering Studies of Fuel Cells
Separation of Gases With Porous Membranes
Study of the Reactions of Hydrogen on Kerogen Under Mild Conditions
Sulfur Control Techniques
Thermal Diffusion in Non-Ideal Aqueous Solutions
Transient Gas Flow
Viscosity of Heavy Hydrocarbons Saturated with Light Gases

STUDENT RESEARCH PROJECTS

Applications of Computational Methods to Simultaneous Reactions
Dynamics of Moisture Diffusion Through Porous Media
Effect of Periodic Perturbations On Diffusion Boundary Layer
Fluid Dynamics in Fuel Cell Cavities
Interaction Virial Coefficients From Dew-Bubble Point Data
Isothermal Adsorption of Carbon Dioxide On a Flat Salt Surface
Non-Equilibrium Boiling of Liquid Hydrocarbon Mixtures
Operating Characteristics of Tapered Fluidized Beds
Particle Distribution in Fluidized Beds
Random Condensation of Amino Acids to Proteins
Regenerative Heat Transfer
Regenerative Separation of Carbon Dioxide
Statistical Methods of Load Estimation
Studies of Reactive Systems in Turbulent Flow
Transport Processes in Fuel Cells

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Litho in U.S.A.