UNITED STATES GOVERNMENT

Memorandum

U.S. CONSUMER PRODUCT
SAFETY COMMISSION
WASHINGTON, D.C. 20207

TO : James F. Hoebel, EX-P

DATE: June 4, 1982

THRU : Walter R. Hobby, Act. AED, Economics

FROM : Barbara J. Morton, ECCP

SUBJECT: Market and Relative Risk Data for Space Heaters and Water Heaters

Economic Analysis has compiled some data on shipments, estimated numbers in use and rates of fires, injuries and deaths for space heaters and water heaters. These data were compiled to assist the Fire-Burn Team in its assessment of the relative risks associated with these products. Gas heating appliances, especially gas-fired space heaters and water heaters, have been specifically identified as products of significant concern.

Space Heaters

Shipments of vented and unvented gas-fired space heaters have fluctuated significantly since 1970 (see Table 1). Vented gas room heater shipments in 1980 were about 124,000 units, and in 1981 shipments were about 77,000 units. This represents a 38 percent decline in shipments in 1981. Unvented gas room heater shipments were 90,000 units in 1980 and 53,000 units in 1981, representing a decline of 41 percent.

Since 1979, vented gas heaters' share of gas-fired space heater shipments has ranged from 60 to 70 percent. Unvented gas heaters accounted for 30 to 40 percent of gas space heater shipments. Before 1977, unvented heater shipments were consistently greater than vented heater shipments; thus, the estimated number in use is greater for unvented heaters. In 1978, when CPSC proposed a ban on unvented gas heaters, manufacturers ceased production temporarily, and unvented heaters accounted for only about 5 percent of that year's shipments.

Portable electric heater shipments totalled about 4.2 million units in 1980 and 4.4 million units in 1981, for an increase of about 5 percent. For the years 1979-1981, electric heaters outsold gas-fired heaters by about 20 to 1.

Economic Analysis employed the CPSC Product Life Model to estimate the number of space heaters in use. As noted in Table 1, these estimates for 1981 are as follows:

Vented Gas Space Heaters	4.2 million units
Unvented Gas Space Heaters	7.3 million units
Portable Electric Heaters	33.4 million units

It should be noted that some of the shipment figures for gas space heaters may understate the actual total shipments, since not all manufacturers reported in all years; this potential underreporting is believed to have a relatively insignificant effect on the estimate of the number of products in use.

Water Heaters

Shipment and number in use data were compiled for gas-fired, oil-fired, and electric water heaters (Table 2). These data indicate that gas-fired water heater shipments (natural and LP gas) declined in 1980 by about three percent, from 2.9 million units in 1979 to 2.8 million units in 1980. Oil-fired water heater shipments were 29,000 units in 1980 which represents a 34 percent decline from 1979. Electric water heater shipments generally increased over the period 1970-1977. For the years 1977 to 1980, the decline in shipments was about 7 percent.

Gas-fired water heaters' share of total water heater shipments was about 50 percent for the years 1978-1980. For this same period natural gas and LP gas water heaters accounted for 86 to 88 percent and 12 to 14 percent of gas-fired water heater shipments respectively. Oil-fired water heaters held a share of 5 to 8 percent from 1978 to 1980. Electric water heaters accounted for about 44 to 47 percent of total water heater shipments for 1978 to 1980.

The estimated numbers of water heaters in use in 1980 are as follows:

Gas-Fired (Natural and LP)	29.8 million units
Oil-Fired	0.3 million units
Electric	20.6 million units

Estimates of Risk

The tables show the calculated number of fires, injuries and deaths per 10,000 products in use for each product category. Gas-fired space heaters and oil-fired water heaters are associated with the highest rates for fires and injuries. Gas-fired space heaters have the highest rate for deaths; vented gas space heaters have the highest rate for carbon monoxide poisoning deaths. It must be noted that the calculated rates are not directly comparable among product groups (e.g., the use patterns for space heaters, which are seasonal, would be different from those for water heaters). Comparisons within the two basic product groups appear reasonable, although differences (e.g., in severity) between kinds of hazards should also be considered in the overall risk assessment process.

Attachments

TABLE 1

SPACE HEATERS

Year	Shipments (Thousand Units): Vented Gas-Fired Space Heaters	Unvented Gas-Fired Space Heaters	Portable Electric Heaters
1970	359	570 (2)	2,840
1971	274	509 (2)	2,750
1972	249	459 (2)	2,920
1973	209	469 (2)	3,170
1974	165	323 (2)	3,620
1975	124	208 (2)	2,990
1976	124	183 (2)	2,750
1977	112 (1)	75	4,120
1978	159 (1)	8	4,470
1979	127 (1)	59	4,460
1980	124 (1)	90	4,200
1981	77	53	4,400 (3)

	Estimated Number In Use (1980) (4)	Accidents per 10,000 products in use (5): Fires	Fire-Related Injuries	Fire-Related Deaths	CO Deaths (6)
Gas-Fired	11,446,000	5.77	.42	.03	.15
Vented	4,158,000	n/a	n/a	n/a	.31
Unvented	7,288,000	n/a	n/a	n/a	.05
Electric	33,355,000	1.38	.13	.01	--

Notes:

(1) These data are not expanded to represent total industry shipments, but are believed to account for substantially all shipments.
(2) These data include gas logs and fireplace inserts, as well as unvented space heaters.
(3) Projected shipments for 1981.
(4) Based on estimates from the CPSC Product Life Model.
(5) Based on Hazard Analysis Division estimates of fires, injuries, and deaths associated with these products.
(6) Although some non-fatal carbon monoxide poisonings occurred, a national estimate is only available for deaths.

Sources:

Gas Appliance Manufacturers Association, (GAMA), "Statistical Highlights", 1967-1976 and 1971-1980.

Memo to Jim Hoebel, EX-P, from Bea Harwood, EPHA-"Status Report, Gas Heating Systems", April 30, 1982.

Economic Analysis, June 1982

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TABLE 2

WATER HEATERS

Shipments (Thousand of Units)

Year	Gas-Fired Water Heaters: Natural Gas	Gas-Fired Water Heaters: LP Gas	Gas-Fired Water Heaters: Total	Oil-Fired Water Heaters	Electric Water Heaters
1970	2400	381	2781	13.6	1680
1971	2600	444	3044	14.7	1920
1972	2700	487	3187	15.6	2300
1973	2600	512	3112	30.4	2600
1974	2200	360	2560	26.7	2500
1975	2300	257	2557	32.0	2200
1976	2700	417	3117	38.0	2600
1977	N/A	N/A	3158	49.3	2700
1978	2600	343	2943	47.1	2700
1979	2500	399	2900	44.1	2700
1980	2500	320	2820	29.2	2500

	Estimated No. in Use 1980 (1)	Accidents per 10,000 products in use (2): Fires	Injuries	Deaths
Gas	29,791,000	3.77	.48	.02
Oil	265,000	33.91	3.01	--
Electric	21,000,000	.52	.02	--

Notes:

(1) The estimated number in use was obtained using the CPSC Product Life Model.

(2) Based on Hazard Analysis Division estimates of fires, and fire-related injuries and deaths associated with these products.

Sources:

Gas Appliance Manufacturers Association,(GAMA), "Statistical Highlights", 1967-1976 and 1971-1980.

Memo to Jim Hoebel, EX-P, from Bea Harwood, EPHA-'Status Report, Gas Heating Systems', April 30, 1982.

Economic Analysis, June 1982

TAB C

UNITED STATES GOVERNMENT

Memorandum

U.S. CONSUMER PRODUCT SAFETY COMMISSION

DATE: 7 MAY 1982

TO : Margaret Neily, Fire & Thermal Burn Team Representative
For: James F. Hoebel, EX-P
Through: William H. King, Jr., Acting Director, ESES

FROM : Dennis McCoskrie, ESES

SUBJECT: Project 10497 -- Gas Heating Systems -- ES Status Report

This report discusses the current status, planned activity, and future recommended activity respecting four specific technical areas that are of immediate concern this year:

Vented Gas-Fired Space Heaters
Carbon Monoxide Detectors
Combination Controls
Fuel-Gas Detectors

The first issue was identified by a recent Hazard Analysis study that associated Vented Gas-Fired Heaters with a significant incidence of carbon-monoxide poisoning. Particularly because the voluntary standard group responsible for this product is responding so promptly on this issue, ES recommends that CPSC participate in the current ANSI Committee effort to upgrade the voluntary standards for this and related products.

The other three issues were identified previously in a June, 1981, report* wherein ES, in response to a request from the New Project Identification Program Manager, outlined a five-point program for work to be directed to the improvement of safety in the use of gas-fired appliances. Two other issues discussed in that report, Flexible Connectors and Cabinet Heaters, are now being examined by the New Project Identification Hazard Team. Depending upon the outcome of their studies, these issues might also become part of the Gas Heating System Project.

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*Memorandum, "Gas-Fired Appliances - Development of Issues"; Charles L. Willis to Robert Northedge, June 19, 1981.

I. Vented Gas-Fired Space Heaters

A. Introduction

Examination of the detailed reports available on CO poisonings caused by vented heaters identify lack of venting as the initial cause. This occurs, in some cases because the user did not connect a vent or flue to a heater that was intended to be used with a vent. More frequently, heaters are connected to vents that are wholly or partially blocked, or to venting systems that are poorly designed or installed. In each of these cases, combustion products from the heater's operation accumulate in the vicinity of the heater so that the oxygen content of the air available to the gas burner is decreased. Depending upon the efficiency of the burner, greatly increased generation of CO will start to occur at some level of decreased oxygen concentration and lethal levels of CO in the room containing the heater can occur shortly afterward.

Current Hazard-Analysis studies indicate a higher rate of carbon-monoxide poisoning deaths attributable to vented gas-fired space heaters than to unvented heaters, which are now regulated by a mandatory consumer product standard. The American National Standards Institute (ANSI) subcommittee responsible for vented heaters (Z21 Subcommittee on Standards for Vented Gas-Fired Warm Air Heaters) has been made aware of these data and also has been informed about CPSC-sponsored research on hazards associated with gas-fired heaters, on voluntary standards for these heaters, and on safety devices which might be suitable to reduce these hazards.

Another concerned industry group, the Gas Appliance Manufacturers Association (GAMA), instituted an Ad Hoc Task Force to study the CPSC-sponsored technical report, "Safety Devices for Gas-Fired Appliances". This report, prepared by the CALSPAN Advanced Technology Center in 1980, discussed CO hazards posed by gravity-vented, gas-fired central heating systems. (A "gravity-vented" furnace exhausts combustion products by means of hot-air convection, rather than by fans or blowers.) One conclusion of this report was that thermal "spill" switches*

*A "spill" switch is so named because it is intended to be activated by combustion gases "spilling" down through the draft hood of a gas heater. A draft hood is required in the heater venting system to allow the up-draft of the hot combustion gases to pull in cooler air from the vicinity of the furnace or heater so as to dilute the exhaust gases and lower the exhaust temperature. This reduces the risk that fire might be caused by heat from the venting system. Normally, then, relatively cool air is flowing into the draft hood and up through the venting system. If the vent should become blocked for any reason, hot combustion gases will be forced out or "spilled" from the draft hood. A temperature actuated switch, placed in the draft-hood opening, then, can be employed to sense the existence of a problem in the venting system and to sound an alarm or automatically turn off the burner.

were the most suitable devices currently available to reduce the risks of CO poisoning from central heaters. This report also pointed out the desirability of writing standards provisions to address this hazard in terms of appliance performance, rather than devise or design requirements.

B. Background

An American Gas Association Laboratories (AGAL) representative on both the ANSI Z21 Subcommittee and the GAMA Ad Hoc Task Force, Stanley L. Blachman, has proposed that a new test-performance requirement be added to the voluntary safety standard for vented gas-fired space heaters (ANSI Z21.11.1-1977). Essentially, this requirement is intended to address the hazards observed in vented gas space heaters, by means of the approach recommended in the CPSC/CALSPAN technical report on safety devices. Shut-down of the heater is called for both when the heater is operated without a vent and when it is operated with a connection to a blocked vent.

Mr. Blachman has written to the members of the ANSI Z21 Subcommittee on Standards for Vented Gas-Fired Warm Air Heaters to propose these new requirements and a method of test to be used to certify heaters as meeting the requirements. He has proposed that consideration of these standards revisions, as well as other issues related to them -- tamper-proof construction, instructions and labels, extension of the requirements to other heating appliances that pose similar hazards -- be considered at the next subcommittee meeting, July 13 and 14, 1982. Informal invitations to this meeting have been offered to CPSC staff members from ES and EP.

Five prototype, vented, gas-fired space heaters, equipped with a variety of thermal "spill" switches, were demonstrated for a representative of ES during a visit at the American Gas Association Laboratories (AGAL) during February of this year. The current version of the voluntary standard requires that all vented heaters be equipped with a draft hood, unless the heater is equipped with a power burner that does not rely on gravity/convection to exhaust combustion gases. The prototype heaters, then, were modified by adding one of a variety of heat-sensitive devices in the air channel of the draft hood. Three different manufacturers, each represented on the ANSI Subcommittee for vented heaters, had prepared these prototypes in response to a request from Mr. Blachman. During the demonstrations, all the systems appeared to respond satisfactorily both to no-vent and to blocked-vent operation.

C. Planned Action

Pending official invitations from the ANSI Subcommittee and CPSC administrative approval, Beatrice Harwood, EPHA and Dennis McCoskrie, ESES, plan to attend the July 13/14 subcommittee meeting. Mr. Blachman requested a preliminary meeting in Bethesda, April 26, to review the hazard-analysis data.

During the third quarter of FY 82, ESES will prepare a technical analysis of the applicability of thermal "spill" switches to reduction of the carbon-monoxide hazard posed by vented gas space heaters. In the same analysis, a comparative discussion of the applicability of Oxygen-Depletion-Sensors (ODS's) to both vented and unvented heaters will be presented.

D. Recommendation

ES recommends that the Commission direct the staff to participate in the development of an upgraded voluntary safety standard for vented gas-fired room heaters (ANSI terminology) as well as other heater standards where the same revision will contribute to safety.

The industry group responsible for the dominant voluntary safety standard for vented heaters is offering CPSC the opportunity and strong encouragement to participate in upgrading this standard to reduce the risk of carbon-monoxide poisoning from these products. Considering the prevalence of these poisonings, and the increasing trend in the use of space or room heaters, work with this subcommittee should be a beneficial investment of CPSC resources.

II. Carbon Monoxide Detectors

A. Introduction

Consumer protection methods to avoid carbon-monoxide poisoning generally provide only partial protection because, for economic reasons, measurements of phenomena <u>associated</u> with the presence of carbon monoxide must be employed to activate an alarm or to shut off the gas appliance, rather than a <u>direct</u> measurement of CO concentration. Gas detectors that can be sold for a suitable price, probably $25.00 or less, usually also respond to other organic gases, such as natural gas, propane, or ethanol, that are frequently present in the same residential areas as gas appliances. As a result, nuisance shut-downs of a gas-fired appliance would tend to be frequent if such detectors are used, because they must be designed to be very sensitive in order to respond adequately to the concentration levels of CO -- 300 parts-per-million (0.03%) or less -- that are critical to protection.

Sensitive and selective CO detection and concentration-measurement means are well known and widely used in analytical laboratories and industrial applications where CO can be expected to be a problem. These instruments usually rely upon some unique physical characteristic of the CO molecule, such as infra-red absorption spectra or molecular weight, and are much too costly to be considered for wide-spread consumer use. Also, much of this instrumentation is too complicated to operate, and to maintain, to be practical for consumer application. Gas analysis technology is a dynamic field, however, and there seems to be a reasonable possibility that a cheap, sensitive CO detector can be developed in the future.

B. Background

Two recent studies of state-of-the-art CO detectors have been performed for CPSC. In "Safety Devices for Gas-Fired Appliances" (CALSPAN, May 1980), Adams and Bullerdiek report that they contacted twenty-seven companies that were identified in various sources as possible sources for consumer-grade gas sensors. Of this group, nine were then found to either manufacture or distribute gas sensors and all of their products appeared to be based upon the same fundamental detector, the Taguchi gas sensor (TGS), a metal-oxide semiconductor that increases conduction in the presence of oxidizable gases. The report presents detailed technical information about several instruments and concludes:

> "We were unable to identify any product intended for the residential market listed by a nationally recognized testing organization as being specifically suitable as an alarm device for carbon monoxide. Manufacturers' claims for their specific products range from no claims at all for detection of CO (and, in fact, discourage any thought in this direction for their product) to making it a primary claim as to suitability. Products apparently not listed by either FM or UL* are being promoted as CO detectors, and other products have claims of FM or UL listings which are ambiguous as to what the listing actually covers versus what the advertising claims or suggests."

Earlier CPSC-sponsored research on CO detectors was performed by the NBS National Engineering Laboratory and is described in a draft report** transmitted in January 1980. This report concluded:

> "Currently available CO devices do not meet the requirements for a low cost residential detector. Available CO detectors cost too much (the cheapest one costs more than $250), are not specific for CO, or have maintenance requirements that

*Factory Mutual Systems or Underwriters Laboratories.
**"Low Cost Residential CO Detectors" (Draft), Ryan Pierson, National Engineering Laboratory, Center for Consumer Product Technology, prepared for Consumer Product Safety Commission, January 1980.

render them unsuitable. The colorimetric devices (tubes, sensitive paper, and pellets) are cheap enough (less than $2.00) but they have a limited service life and are not designed to provide an automatic alarm."

In addition, this report recommended against initiating a government-sponsored program to develop a low cost CO detector, but recommended that appropriate performance specifications and test procedures for low-cost residential CO detectors be developed as soon as possible.

C. Planned Action

In FY 82, the only action contemplated by ES, at present, is monitoring the scientific and commercial literature for any mention of suitable CO detectors, and informal consultation with CPSC and NBS personnel who are likely to be aware of new developments in this field.

D. Recommendation

In FY 82, if possible, or in FY 83, place a contract with some suitable organization to develop performance specifications and test procedures to serve as the basis for possible development of a residential CO detector/alarm/control system suitable for consumer use. Alternatively, it may be possible to interest some industry group or voluntary-standard-writing group under ANSI to develop the profile of such a consumer instrument, with participation by CPSC. If this is possible, it is recommended in preference to employment of a contractor.

III. Combination Controls

A. Introduction

Safe operation of many gas appliances is dependent upon reliability of the combination control that is supposed to prevent flow of fuel gas into the appliance, except when the pilot flame or other ignition means is functioning correctly. Failure of this safety-valve function of the combination control can cause release of large volumes of fuel gas into the appliance and the room where it is located thus creating the risk of a serious fire or explosion. These devices are called "combination" controls because they usually incorporate the gas valve operated by the appliance's temperature control as well as the manual controls that are used for safe relighting of the pilot flame, when it has been extinguished for some reason.

Failures of combination controls have caused many serious accidents during the history of CPSC and, as a result, a series of investigations under Section 15 of the CPSA have been conducted. Several substantial recall and repair campaigns have been required.

This history leads to the question of a possible generic problem with combination controls and consideration of CPSC action that might be more effective than acting on one make and model at a time, under CPSA Section 15.

B. Background

Most of the information that CPSC has about gas combination-control-related fires and injuries is contained in the case files of individual Section 15 investigations. ES has not made a comprehensive analysis of these various kinds of reports to try to establish whether a pattern is apparent that could point to a generic problem with combination controls or a particular characteristic of combination controls that are involved in fires, as opposed to those that are not.

What has been done, and is being done, is analysis of reports about particular models to try to identify a product defect that is associated with causing the fires. No statistical analysis of the information in the Section 15 files has been made, but detailed review of several of them has led to some preliminary observations:

1. Serious fires, explosions, and injuries occur much more frequently in LP-gas installations than in natural-gas-fired appliances.
2. Many combination controls suspected of contributing to the occurrence of a fire have been in service for more than ten years and have been damaged by mishandling as a result of malfunction of the control, or misunderstanding of the use of the control when relighting the pilot.
3. Combination controls that are suspected of being involved in a fire incident often are found to be internally corroded, or to contain foreign materials that could cause malfunctions. "Drips" or drip legs, devices to collect condensate and other foreign materials from the gas piping system usually are not installed to protect individual gas appliances.
4. CPSC In-Depth-Investigation reports and other reports available about fire incidents that may involve gas combination controls rarely contain information about the user's experience with the control before the fire incident.

C. Planned Action

To resolve the question of the existence of a generic safety problem with gas combination controls, an engineering evaluation of the fire incident data is needed. There is the question, however, of the adequacy of the information available within CPSC to support a useful evaluation.

During the remainder of FY 82, ES in cooperation with HIA, plans to perform a survey and sampling of available fire incident and other CPSC data pertinent to gas combination controls, with the goal of planning an engineering hazard evaluation, if it is found that adequate information is available.

Availability of resources to perform this survey will depend upon the level of involvement, if any, in the development of the voluntary standard for vented gas heaters.

D. Recommendation

The possibility of a generic fire-safety problem in gas combination controls should be investigated. More detailed reports of user interaction with these controls before fire incidents are needed, to determine the mechanism of failure, in the cases where there has been a failure.

IV. Fuel-Gas Detectors

A. Introduction

While combination controls and other safety devices probably can be improved so as to decrease the number of serious fuel-gas (gases supplied as "natural" gas or liquefied-petroleum, LP, gas) leaks that occur, another approach to reducing the injuries and deaths that are caused by gas fires and explosions would be the use of a warning device that detects dangerous concentrations of fuel gas and, perhaps, also other flammable vapors. An audible signal, for instance, could warn the user that a dangerous leak has occurred, so that he could turn off the gas supply to the appliance and send for assistance from his gas supplier before ignition occurs (or, at least, if ignition is going to occur, the user can remain at a safe distance.)

B. Background

ES is not aware of comprehensive information about fuel-gas detectors that is available within CPSC. There are some commercial instruments being marketed and there is a draft voluntary standard (UL-1484, Standard for Residential Gas

Detectors), but these detectors have not been investigated to determine whether or not they could prevent many of the fires and injuries reported to be associated with gas appliances. Adequacy and reliability of an instrument that can be sold for an acceptable price needs to be evaluated, and there are some non-engineering aspects that also require study -- e.g., will the economic and social strata of consumers who are experiencing serious gas explosions be very likely to purchase and install gas detectors, if they were made available?

C. Planned Action

During FY 82, ES will plan a technical study project, to be proposed as part of the Fire and Thermal Burn program for FY 83 or FY 84. Also ES will contact Underwriters Laboratories to review the present status of the voluntary standard for residential gas detectors.

D. Recommendation

ES recommends a two-stage approach to this issue:

First, a determination should be made of the applicability of fuel-gas detectors to reduction of deaths, injuries, and damage from gas-appliance related fires and explosions. This study would involve principally Epidemiology, Human Factors, and Economics, with ES providing a moderate level of technical support. The objective of the study would be to determine, from the information that we have about gas-appliance fires, if the greater availability and use of fuel-gas detectors would be likely to effect an appreciable reduction in casualties and damage.

Depending upon the conclusions derived from the first study, then a technical study of fuel-gas detectors may be appropriate. Starting with an appropriate consumer price, perhaps determined during the first study, available technology would be evaluated to determine if a suitably effective and reliable instrument is feasible. This might be accomplished by means of a development contract, with the American Gas Association Laboratories considered to be one potential contractor.

UNITED STATES GOVERNMENT

Memorandum

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U.S. CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, D.C. 20207

~~RESTRICTED~~

TO : Douglas L. Noble, Program Manager for Emerging Hazards, OPM

DATE: JUN 10 1982

FROM : Nick Marchica, Program Manager for Product Safety Assessment, Office of Program Management *Nick Marchica*

SUBJECT: Flexible Gas Connectors

Attached is a discussion paper prepared by the Product Safety Assessment team (PSA) on flexible gas connectors. The discussion paper was prepared in anticipation of referral of this matter to the Emerging Hazards Program by the Corrective Actions Division.

Attachment

Discussion Paper

on

Flexible Gas Connectors

Product Safety Assessment Team
June, 1982

Discussion Paper: Flexible Gas Connectors

The Product

Flexible gas connectors are somewhat misnamed in that they are not designed to withstand frequent flexing. These connectors are constructed of corrugated metal (brass or stainless steel), and may be sheathed in plastic or rubber. Flexible connectors designed for residential use are typically 1/2 inch in diameter, and range in length from 3 to 6 feet.

These flexible connectors are designed for initial hookup of gas appliances. After hookup, the appliance can then be moved flush to a wall for permanent installation. The connector would allow for infrequent movement of the appliance, such as in cleaning or repair, but is not intended for frequent stress. Connectors are often replaced when the appliance is moved, as in during appliance replacement or the sale of the residence.

When gas appliances were first introduced, the appliance was permanently installed as much as several feet away from walls to allow for gas line hookup. The advent of flexible connectors allow for a more convenient location for the appliance, and a more efficient use of floor space. Flexible gas connectors began to experience wide use in the mid-1950's.

Background

A chronology of Commission involvement with flexible gas connectors is provided at Tab A. A supplemental package containing the documents referenced in the chronology has been forwarded to the Program Manager for Emerging Hazards.

Much of the Commission's work involved flexible gas connectors manufactured by the Cobra Metal Hose Company of Chicago, Illinois. This company had been out of business for over 12 years at the time (1979) the Public Service Company of Colorado experienced problems with fire/explosions related to the product. The Public Service Company of Colorado alerted the Commission of approximately twenty gas leaks resulting from the "Cobra" flexible gas connector. The problem was that these connectors were constructed with the end ferrules soldered to the bellows sections by only its wall thickness, which allows only a minimum of strength to resist breaking.

The Commission corresponded with the American Gas Association (AGA) in mid-December 1979, apprising them of the problem with the "Cobra" flexible gas connector and forwarding a copy of the statement the Commission developed to inform consumers of the hazards associated with this product. In addition, similar letters to (1) the National LP-Gas Association, Arlington, Virginia; (2) American Public Gas Association, Washington, D.C.; (3) Department of Defense (DOD), Washington, D.C.; and (4) Department of Housing and Urban Development (HUD), Washington, D.C. were sent out early in January, 1980.

The letters were forwarded to utility companies to inform them of the possible hazards involved and to suggest possible ways of alerting the consumer. Letting utility companies decide how to spread the word in their area was considered to be the safest and most efficient way. DOD and HUD were alerted so that they could determine the best way to alert residents of military bases, here and abroad, and residents of public housing units. The Commission staff did not want to cause possible additional hazards by urging the public in any national press release, to check out the problem themselves.

In July, 1981 the NPI program prepared a memorandum for the Executive Director in which flexible gas connectors was one of five issues discussed for focusing CPSC activities on gas-fired appliance hazards.

In October, 1981 the PSA completed engineering analyses of two flexible gas connectors manufactured by American Metal Products Corporation for the Corrective Actions Division (CACA). The analyses showed failure of the connectors by external stress corrosion. In addition, in December, 1981 the Fire Prevention Bureau of the city of Saginaw, Michigan informed the Commission (CACA) of an excessive number of fires due to the failure of flexible gas connectors. The PSA informally examined the units and noted separation of the corrugated metal end to the soldered joint.

CACA is of the opinion that the problems are generic in nature. In anticipation of referral of this matter to the Emerging Hazards Program, the Program Manager for Emerging Hazards requested the PSA to prepare a discussion paper on flexible gas connectors.

Summary of Injury Information (Tab B)

The following CPSC data bases were reviewed for the years 1973 - 1982:

Data Base Source	No. of Reports
°Injury or Potential Injury Incidents (IPII)	36
°In-depth Investigations (INDP)	13
°Death Certificates (DTHS & DCRT)	0
Total	49

Of the 49 incidents found in the IPII and INDP files which referenced a flexible gas connector, 17 appeared to be within the scope of the assignment. This includes 15 explosion/fires and two gas leaks. Two fires occurred after the appliance was moved for cleaning, and a gas leak occurred when the flexible gas connector broke while being moved. None of the incidents specifically reported propane gas while 7 incidents were related to natural gas. The type of gas in the remaining incidents was not mentioned.

Data bases were searched under product code 0607-Gas Pipes, Pipe Fittings or Distribution systems and code 0131-Propane, L.P. or Butane Tanks or Fittings. In addition a word search was done under all codes using "connector" in conjunction with Gas, LP or LPG. The death certificate file contained information on 315 deaths from fires and explosions caused from gas leaks but in no instance was a flexible gas connector specifically mentioned.

The following manufacturers were identified from the IPII and INDP data bases:

Manufacturers	No. of Incidents
Cobra	3
[redacted]	2
	1
	1

For the purposes of this study Epidemiology confined the data to those cases in which a flexible gas connector was mentioned. It should be noted that CPSC hazard data bases contain hundreds of incidents of fires and explosions relating to major appliances such as ranges, stoves, dryers, washers, etc. Some of these incidents may have been caused by flexible gas connectors, but the exact cause could not be determined or was not reported.

Summary of Economic Information (Tab C)

Manufacturers

Manufacturers of the product have stated that in order to be offered for sale in the U.S., flexible gas connectors must be listed by the AGA. This is because the model building codes require connectors to be listed by the AGA as complying with the applicable ANSI or UL standards. There are 15 manufacturers of AGA - listed flexible gas connectors, as of July, 1981.

Sales and Uses

Annual sales of flexible gas connectors bear a close relationship to the number of gas appliances sold to consumers. Industry sources estimate annual domestic residential sales at 1.7 - 2.6 million units; of this 10 - 15 percent are sold as replacement connectors for existing appliances. The remaining portion is used in conjunction with new gas appliances.

According to Mr. Jack Langmead of the Gas Appliance Manufacturers Association (GAMA), flexible connectors are almost always used (where permitted by law) with free-standing gas ranges, and are sometimes found with gas dryers. Other gas products which may use flexible connectors are built-in ovens and ranges, room heaters, and gas fireplace burners. These connectors may also be used with water heaters and central heating units, but such use is likely to be insignificant.

Numbers in Use

The AGA has stated that there were some 43.5 million residential gas customers in 1980. Of these, GAMA reports that each residence will contain 2 or 3 of the 4 main types of gas appliances (ranges, water heaters, clothes dryers, and central heaters). Thus, it is likely that the vast majority of these households would contain 1 or more flexible gas connectors. Households where the sole use of gas is for central heating, however, would not contain flexible connectors.

The 1977 Annual Housing Survey stated that about 50 percent of all residential cooking fuel was natural or LP gas. If flexible connectors were used in each of these ranges, the number of connectors in use would approach 45 million. Industry spokesmen have estimated the number of flexible connectors currently in use at 40 - 50 million units.

Product Life

According to industry sources, flexible gas connectors have an expected product life of 10 - 15 years. However, the useful life of the product may be considerably shortened if the connectors are subject to frequent flexing.

Engineering Information (Tab D)

What are the effects of contaminants on the product?

Flexible metal connectors used on gas appliances in homes may be subjected to any of a number of corrosive environments, both internally and externally. The corrosive contaminants in fuel gases are usually sulfur compounds found in "sour" gas in certain small, restricted parts of the country. Most natural and LP gas is refined prior to entry into gas pipelines or sale to consumers and is relatively benign. In areas where "sour" gas is sold, flexible connectors are either stainless steel or double walled, with the inner wall being made of aluminum. Internal corrosion is not considered to be a significant problem.

However, as shown in a 1972 survey by the AGA laboratories, 192 of 318 connectors (about 60%) examined failed by cracking in the corrugations, presumably as a result of external stress corrosion. Seventy-eight percent of the connectors replaced were on kitchen ranges, even though the survey showed only 60% of the connectors were used on kitchen ranges. Thus, the kitchen seems to be one of the more hostile environments for connectors. The most corrosive of the several agents to which the flexible metal connectors are exposed seems to be ammonia. It evaporates from such products as window cleaners, cleansers, wax removers, floor cleaners, waxes, dish washing materials. In addition to those products containing ammonia, there are also those containing amines, surfactants and quaternary ammonium compounds, such as oven cleaners, sizings and fabric softeners which may contribute to the problem. Some of these will also be used in the vicinity of dryers, in laundry rooms, and space heaters throughout the house.

The mechanisms by which brasses corrode in contact with ammonia, either in liquid or vapor form, are well understood. Certain types of brass should not be used in a stressed condition in the presence of even intermittent low concentrations of ammonia.

Coating the connectors is frequently required in ammonia atmospheres; both PVC and epoxy coatings are used. However, neither has the elasticity required if there is much movement, particularly extension of the flexible connectors. Once the coating has been broken, corrosion progresses in the cracks.

Stainless steel flexible connectors are also made. For a while, it was felt that they might fail by chloride ion corrosion, for they may be exposed to table salt in the kitchen or household bleach (sodium hypochlorite) in the laundry room. However, Engineering Sciences is not aware of any failures. Tests devised to expose stainless steel flexible connectors under stress to chloride corrosion at elevated temperatures have not produced failures. Stainless steel flexible connectors also pass the ammonia and season cracking tests.

Summary and evaluation of existing voluntary standards

There are three major voluntary standards in use in the United States for flexible gas appliance connectors. These are: (1) ANSI Z21.24 (1973), Z21.24a (1976) and Z21.24b (1979) - Metal Connectors for Gas Appliances; (2) ANSI Z21.45 (1979) and Z21.45a (1981) - Flexible Connectors of other than All-Metal Construction for Gas Appliances; and (3) UL 569 - Pigtails and Flexible Hose Connectors for LP-Gas.

The ANSI standards pertain to all natural, manufactured, mixed and LP-gases and LP gas-air mixtures. UL 569 pertains to LP-gas.

All three standards define the material of construction, dimensions, fittings, instructions for proper usage, marking and a series of performance tests for strength, corrosion resistance and recognition of fittings. In addition, ANSI Z21.45 and Z21.45a, and UL 569 have tests for the performance and durability of the non-metallic surfaces of the tubing.

ANSI Z21.24, Z21.24a and Z21.24b - Metal Connectors for Gas Appliances, seems to be a satisfactory standard, coping with the problems that have befallen metal connectors in the past (i.e. separation of the connector at the soldered joint and external stress corrosion). Engineering Sciences understands that it is no longer industrial practice to solder or braze end ferrules on to the flexible metal tubing, but to deform the tubing ends in the union connectors.

ANSI Z21.45 and Z21.45a - Flexible Connectors of Other than All-Metal Construction for Gas Appliances, seems to answer the current needs for flexible metal connectors with linings or external coverings. However, there is no mention of soldered or brazed ends which were the start of one type of failure. It is possible that soldered or brazed ends might effectively be precluded by the acid treatments prior to the season cracking test.

UL 569 - Pigtails and Flexible Hose Connectors for LP-Gas, has no provisions, pertaining to pigtails, for corrosion resistance to ammonia for stresses acquired in use. The mercurous nitrate test usually does not detect these small stresses; it detects only major residual stresses, such as may be present from manufacturing, if the post-forming annealing process is defective. However, because most of the pigtails made to the standard are soft-annealed copper, this omission may not be serious.

Summary and evaluation of the requirements for flexible gas connectors in the Model Codes

The four model building codes, which are the basis for the majority of state and local codes used in the United States, have similar requirements for listed flexible gas connectors. These model code organizations are the Council of American Building Officials (CABO), the Southern Building Code Congress International (SBCCI), the Building Officials and Code Administrators (BOCA), and the International Conference of Building Code Officials (ICBO).

In addition to the four basic codes, there is a National Fuel Gas Code, approved by ANSI Committee Z223, which is designed to satisfy the immediate needs of the gas industry for a single installation code for gas appliances and equipment. This National Fuel Gas Code is designated as NFPA 54 or ANSI Z223. The latest version is the 1980 edition.

Some of the requirements addressed are the length of the connector, that connectors should not be concealed or go through walls, floors or partitions and that the connectors be listed.

All of these codes refer back to listed connectors. This means listed by the American Gas Association as complying with ANSI standards Z21.24, .24(a), .24(b) and Z21.45 and .45(a). For LP-gas, listed connectors also include those complying with UL 569.

Summary of American Gas Association Special Announcements on Flexible Metal Connectors

There have been two Special Announcements on flexible metal connectors published in the Directory of the American Gas Association Laboratories in recent years. These are still appearing in the current issue, dated January 1, 1982.

The first discusses the problems encountered with the COBRA connector. The second discusses the Masco Corporation (American Metal Products Co.) recall of certain flexible connectors (CPSC ID 79-172).

Summary/Discussion

There were 15 explosion/fires and two gas leaks in the CPSC data bases for the years 1973-1982 in which flexible gas connectors were referenced. Two fires occurred after the appliance was moved for cleaning, and a gas leak occurred when the flexible gas connector broke while being moved. CPSC hazard data bases contain hundreds of incidents of fires and explosions relating to major appliances such as ranges, stoves, dryers, washers, etc. Some of these incidents may have been caused by flexible gas connectors but the exact cause could not be determined or was not reported.

Industry spokesmen have estimated the number of flexible connectors currently in use at 40-50 million units. According to industry sources, flexible gas connectors have an expected product life of 10-15 years. The useful life of the product may be considerably shortened if the connectors are subject to frequent flexing.

The kitchen seems to be one of the more hostile environments for connectors. The most corrosive of the several agents to which the flexible metal connectors are exposed is ammonia. Certain types of brass should not be used in a stressed condition in the presence of even intermittent low concentrations of ammonia. Coating the connectors is frequently required in ammonia atmospheres; both PVC and epoxy coatings are used. However, neither has the elasticity required if there is much movement, particularly extension of the flexible connectors. Once the coating has been broken, corrosion progresses in the cracks.

The existing voluntary standards seem to be satisfactory, coping with the problems that have befallen metal connectors in the past. However, it is reasonable to assume that consumers will move their gas appliances, for example for cleaning purposes, which will considerably shorten the useful life of the product.

Recommendation

The PSA team recommends that the Program Manager for Emerging Hazards consider the following:

(1) Meeting with those parties involved with the gas appliance system (manufacturers of flexible gas connectors, gas appliance manufacturers, AGA and other associations) to discuss the problem of frequent movement of gas appliances using flexible gas connectors and possible remedies.

(2) As possible remedies:

(a) A joint CPSC/Industry information and education effort. For example, the development of a consumer pamphlet and/or a bill stuffer discussing the problem of frequent movement. This might include an explanation that flexible gas connectors are used for ease of installation, they are not intended for frequent movement and that they are often replaced during appliance replacement or the sale of the residence.

(b) Voluntary labeling by gas appliance manufacturers alerting the consumer to the potential problems associated with flexible gas connectors attached to the product.

3. Determining the number of jurisdictions that currently ban the use of flexible gas connectors to gain insight into the extent of the ban on the use of this product.

In addition, the Corrective Actions Division recommends that the Program Manager for Emerging Hazards consider encouraging the flexible gas connector industry to upgrade and improve the connectors by using alternative materials to brass. The assumption is that frequent movement of the connector coupled with exposure to an ammonia environment will lead to failure of the product by failure of the metal and stress corrosion cracking. If this recommendation is followed, the PSA team further recommends that a sufficient number of failed samples be obtained and analyzed to establish the scope of the problem.

A

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Flexible Gas Connectors

Chronology of Commission Involvement

2/75 Engineering Sciences, through NBS, analyzed the failure of a flexible brass gas appliance connector. Failure resulted from the ammoniacal leak testing fluid. (NBSIR 75-669 Failure of flexible Brass Gas Appliance Connector, 2/75).

9/21/76 J.R. Ambrose, Corrosion and Electrodeposition Section, NBS memorandum to J.P. Talentino, Bureau of Engineering Sciences, CPSC. NBS was asked if it was worthwhile to do anything in this area? NBS response included the acknowledgement that brass will crack in an ammonia atmosphere and it was questionable as to whether resources should be expended as to how fast and under what conditions. Further, NBS stated that new techniques could not predict service life on other materials possibly considered for replacement.

1/77 Gas Appliance Connector Survey (Phase I). 65 commercially available flexible gas connectors, representing 11 manufacturers, were examined for conformance with the American National Standard Institute (ANSI) standard Z21.24. Those dated 1976 and later were examined under ANSI Z21.24(a).

4/77 Gas Appliance Connector Survey (Phase II). (1) Five connectors were tested for resistance to flexure cracking by ANSI Z21.24 Section 4.3; all passed. (2) Four connectors were tested for resistance to season cracking by Section 4.6. The brass connector failed, the stainless steel connector passed and the two epoxy-coated brass connectors failed. (3) Six connectors were subjected to the test for resistance to ammonia atmospheres in Section 4.10. The two brass connectors and the damaged epoxy-coated brass connector failed. The stainless steel brass/aluminum connector and the undamaged epoxy-coated brass connector passed.

3/15/79 Public Service Company of Colorado reports to Denver Area Office a hazard pattern in leaking flexible metal gas tubing connectors manufactured by Cobra Metal Hose, Chicago, Illinois. Denver Area Office forwards information to Product Defect Identification Division (CEPD).

4/2/79 CEPD decides cannot take action since company was out of business.

4/30/79 Denver Area Office advises Public Service Company official to consider filing a petition since PSC was still concerned about the hazard and wanted CPSC to act.

7/19/79 The CEPD Hazard Assessment Committee determined that a component steel nut was manufactured out of specification on a flexible gas connector manufactured by Masco Corporation (RP 79-152) permitting a potential gas leak thus posing a fire hazard.

10/23/79 Public Service Company of Colorado provides further information to Denver Area Office about increasing number of defects discovered in gas connectors manufactured by Cobra. Denver Area Office forwards information to AED Field Operations with recommendation to contact AGA and jointly resolve the problem.

11/5/79 Information from Denver Area Office discussed at the Emerging Hazards Program Team Meeting. AGA to be contacted and asked whether they would want to cooperate with CPSC in addressing the problem.

11/19/79 Emerging Hazards Status Report. Chicago Area Office to attempt to obtain Cobra distribution records. AGA willing to cooperate with CPSC to work out a public notification of the problem in conjunction with local gas companies.

11/21/79 CEPD determines that Masco Corporation's corrective action plan adequately addresses the hazard presented by the product. The corrective action is accepted and will be monitored (ID 79-172).

12/7/79 Chicago Area Office determines that D.K. Manufacturing Company (manufacturer of Cobra) was liquidated in 1968. Distribution records were probably not available.

12/7/79 AGA details actions it would take: (1) Transmit to member companies recommendations made by CPSC; (2) Publish a similar notice in AGA's Directory of Certified Appliances and Accessories; (3) Recommend that member companies immediately consider whatever actions they would deem appropriate in order to comply with the recommendations; (4) Recommend that members distribute, by letter, bill inserts or other appropriate methods a notice concerning proper procedures to be followed by the customer should the customer smell gas in the home.

12/14/79 Commission staff (OEX) requests the assistance and cooperation of AGA. Commission staff developed a statement for use by AGA.

12/21/79 AGA details its actions including 12/19/79 Safety Bulletin to all delegates of AGA member companies.

1/2/80 Commission staff (OEX) letters to the National LP-Gas Association, American Public Gas Association (APGA), Department of Defense and Department of Housing and Urban Development.

1/30/80 National LP-Gas Association (NLPGA) Correspondence discussing 1/28/80 Safety Bulletin to marketeter members.

2/21/80 Public Service Company of Colorado press conference on flexible gas connectors.

2/21/80 Department of Housing and Urban Development informs Commission that HUD will issue an appropriate notice to Public Housing Agencies.

5/80 CPSC MEMO article on flexible gas connectors.

8/1/80 CPSC Regional and District Office employee survey to determine who had seen a notice in their gas bill regarding Cobra gas connectors. A low number of people recalled seeing the notice.

8/18/80 PM, Emerging Hazards memoranda to Director, CEPD on additional
8/19/80 reports of potentially defective gas connectors for appliances. (From Public Service Company of Colorado).

9/80 PM, Emerging Hazards informally contacts AGA, NLPGA and APGA to obtain reaction to request for issuance of new letters to marketers. AGA: Has sent out at least two subsequent notifications. Any new campaigns should include manufacturers also. NLPGA: willing to cooperate but would suggest recall of specific products. APGA: reserved making any commitments.

9/26/80 AGA transmits to Commission 3/20/80 service Bulletin sent customer service department managers, customer activities committee and customer and utilization committee. Bulletin was expanded to assist in identifying those additional flexible gas connectors which have shown a potential for failure. AGA also expressed a willingness to assist the Commission in the distribution of further notifications.

10/17/80 CEPD requests the AGA Laboratories to (1) identify all firms who were certified by AGA to manufacture the old style (pre-1967 ANSI standard revision) flexible gas appliance connectors; (2) provide information regarding the current status of the firms; and (3) indicate whether the nine firms identified by CEPD in the letter manufactured the old style gas appliance connector.

10/31/80 CEPD closes the file on Masco Corporation (ID 79-172).

12/23/80 AGA provides partial response to CEPD's request. AGA provided attachments identifying by name and last known address those firms that at one time or another between 1950 and 1968 had AGA Directory listings of flexible metal connectors.

2/27/81 AGA provides additional information to CEPD received from their Pacific Coast Branch Laboratories.

5/1/81 New Project Identification (NPI) Program discussion paper on gas-fired appliances prepared for the Executive Director. (Gas pipes, fittings, and distribution systems was a discussion item. Leaks in gas line connectors, both flexible and rigid, resulting in explosions was the major hazard pattern for this group.)

7/2/81 PSA requested by CACA to review IDIs and samples with respect to CA 81-2664 (American Metal Products Corporation).

7/29/81 NPI Program memorandum to the Executive Director on specific issues which could be used for focusing future CPSC activities on gas-fired appliance hazards. (Flexible gas connectors was one of five issues discussed).

8/13/81 Product Safety Assessment (PSA) Program completes injury data base review for incidents involving flexible gas connectors for the Corrective Actions Division (CACA). Twelve incidents were found.

10/6/81 PSA program completes engineering analyses of two American Metal Products Corporation flexible gas connectors for CACA (CA 81-2664). Both connectors failed by stress corrosion of the brass metal of which the connectors were made. Recommendation was that brass not be used as a material for this application.

12/7/81 The Fire Prevention Bureau of the city of Saginaw, Michigan informed the Commission of an excessive number of fires due to the failure of flexible gas connectors.

4/7/82 Program Manager for Emerging Hazards requests the PSA program prepare a discussion paper on flexible gas connectors.

4/27/82 CACA preliminary determination not to proceed on CA 81-2664 (American Metal Products Corporation).

UNITED STATES GOVERNMENT

RESTRICTED

U.S. CONSUMER PRODUCT SAFETY COMMISSION

Memorandum

Nick Marchica, EX-P
Through: Ross Koeser, EPHA R.K.

DATE: MAY 1982

Sheila Kelly, EPHA

Data Base Review of Incidents Involving Flexible Gas Connectors.

In response to your request for a compilation of incidents involving flexible gas connectors, the following CPSC data bases were reviewed for the years 1973-1982:

Data Base Source	No. of Reports
. Injury or Potential Injury Incidents (IPII)	36
. In-depth Investigations (INDP)	13
. Death Certificates (DTHS & DCRT)	0
Total	49

Of the 49 incidents found in our IPII and INDP files which referenced a flexible gas connector, 17 appeared to be within the scope of this assignment. We have taken these 17 incidents involving flexible gas connectors and provided the attached table which is an incident listing grouped by hazard pattern. This table includes 15 explosion/fires and two gas leaks. None of the incidents specifically reported propane gas while 7 incidents were related to natural gas. The type of gas in the remaining incidents was not mentioned. We have attached the hard copy for each of the 17 incidents mentioned in the table.

Data bases were searched under product code 0607-Gas Pipes, Pipe Fittings or Distribution systems and code 0131-Propane, L.P. or Butane Tanks or Fittings. In addition a word search was done under all codes using "connector" in conjunction with Gas, LP or LPG. The death certificate file contained information on 315 deaths from fires and explosions caused from gas leaks but in no instance was a flexible gas connector specifically mentioned.

The following manufacturers were identified from the IPII and INDP data bases:

Manufacturers	No. of Incidents
Cobra	3
[redacted]	2
	1
	1

For the purposes of this study we confined our data to those cases in which a flexible gas connector was mentioned. It should be noted that CPSC hazard data bases contain hundreds of incidents of fires and explosions relating to major appliances such as ranges, stoves, dryers, washers, etc. Some of these incidents may have been caused by flexible gas connectors, but the exact cause could not be determined or was not reported.

Attachments

RESTRICTED

FLEXIBLE GAS CONNECTORS

	INDP	IPII	DIAGNOSIS: DEATHS	DIAGNOSIS: INJURY	MANUFACTURER	YEAR OF INCIDENT	TYPE OF GAS	HAZARD SYNOPSIS
1.	820204CEP2115					1/30/82	NAT	Fire - Range moved for cleaning caused leak in flex. gas line
2.		CIC0090AD				12/27/81	unk	Fire - Flexible gas line connecting gas to kitchen stove developed leak
3.	810404CEP2270					3/4/81	unk	Fire - leak in flexible metal gas connector leading from range
4.	810404CEP2107					3/18/81	unk	Fire - Flexible metal gas hose broke behind kitchen range
5.	810203L057011				Cobra	2/3/81	Nat	Fire - Flexible gas connector to kitchen range
6.		D110266AO				1/-/81	unk	Fire - started from a connection on gas line to kitchen wall
7.	✓ 810120MIN5041				[redacted]	12/20/80	unk	Fire - Stove moved for cleaning caused leak in flexible gas line
8.	810107IIIA2049				[redacted]	12/2/80	Nat	Fire - flexible gas line to kitchen stove developed leak
9.	801214CEP2641		2		[redacted]	11/1/80	unk	Fire - leak in flexible (brass) gas connector behind kitchen range
10.	809121MII5031				[redacted]	8/26/80	Nat	Fire - Flexible gas connector leaked located behind stove
11	800725BEP0002		1			7/1/80		Exp/Fire - Gas leak in flexible gas connector connecting stove
12	801219BEP7201		2	1		1/1/78	unk	Fire - Flexible fitting from gas hose to wall heater apparently leaked
13		M09204840				8/26/80	unk	Explosion - Gas leak in flexible tubing connected to gas stove
14.	791212OPY7185			minor injury to [illegible]		11/12/77	Nat	Explosion - leak in flex. gas (brass) connector running to stove
15		E040067AD			Cobra	4/6/80	unk	Gas leak - Connector hose loosened hose fell off
16.	791123IIIA0141					10/3/79	unk	Gas leak - Copper flexible gas line broke while being moved
17.		E930041AD			Cobra	3/15/79	unk	Fire - defective gas line connector (bottom of hose [illegible])

C

UNITED STATES GOVERNMENT

Memorandum

U.S. CONSUMER PRODUCT
SAFETY COMMISSION
WASHINGTON, D.C. 20207

TO : Douglas L. Noble, EX-P
THRU: Nick Marchica, EX-P, PSA
THRU: Walter R. Hobby, Acting AED, Economics
FROM : Terrance R. Karels, ECCS

DATE: May 7, 1982

SUBJECT: Flexible Gas Connectors - PSA Request #455

This is in response to your request for information regarding flexible gas connectors. You specifically asked for information on the number of manufacturers, sales, uses, and the expected life of the product.

The Product

Flexible gas connectors are somewhat misnamed in that they are not designed to withstand frequent flexing. These connectors are constructed of corrugated metal (brass or stainless steel), and may be sheathed in plastic or rubber. Flexible connectors designed for residential use are typically 1/2 inch in diameter, and range in length from 3 to 6 feet.

These flexible connectors are designed for initial hookup of gas appliances. After hookup, the appliance can then be moved flush to a wall for permanent installation. The connector would allow for infrequent movement of the appliance, such as in cleaning or repair, but is not intended for frequent stress. Connectors are often replaced when the appliance is moved, as in during appliance replacement or the sale of the residence.

When gas appliances were first introduced, the appliance was permanently installed as much as several feet away from walls to allow for gas line hookup. The advent of flexible connectors allow for a more convenient location for the appliance, and a more efficient use of floor space. Flexible gas conectors began to experience wide use in the mid-1950's.

Manufacturers

In order to be offered for sale in the U.S., flexible gas connectors must be certified by the American Gas Association (AGA). Following is a list of the 15 manufacturers of AGA - certified flexible gas connectors, complete as of July, 1981:

[redacted]

Los Angeles, CA
Waterbury, CT
Los Angeles, CA
Downers Grove, IL
Detroit, MI
Pittsburgh, PA
Port Jervis, NY
Bartlett, IL
Palioma, CA
Riverdale, NJ
Osaka, Japan
Cucamonga, CA
Tokyo, Japan
Osaka, Japan
Los Angeles, CA

Sales and Uses

Annual sales of flexible gas connectors bear a close relationship to the number of gas appliances sold to consumers. Industry sources estimate annual domestic residential sales at 1.7-2.6 million units; of this 10-15 percent are sold as replacement connectors for existing appliances. The remaining portion is used in conjunction with new gas appliances.

According to Mr. Jack Langmead of the Gas Appliance Manufacturers Association (GAMA), flexible connectors are almost always used (where permitted by law) with free-standing gas ranges, and are sometimes found with gas dryers. Other gas products which may use flexible connectors are built-in ovens and ranges, room heaters, and gas fireplace burners. These connectors may also be used with water heaters and central heating units, but such use is likely to be insignificant.

Numbers in Use

The AGA has stated that there were some 43.5 million residential gas customers in 1980. Of these, GAMA reports that each residence will contain 2 or 3 of the 4 main types of gas appliances (ranges, water heaters, clothes dryers, and central heaters). Thus, it is likely that the vast majority of these households would contain 1 or more flexible gas connectors. Households where the sole use of gas is for central heating, however, would not contain flexible connectors.

The 1977 Annual Housing Survey stated that about 50 percent of all residential cooking fuel was natural or LP gas. If flexible connectors were used in each of these ranges, the number of connectors in use would approach 45 million. Industry spokesmen have estimated the number of flexible connectors currently in use at 40-50 million units.

Product Life

According to industry sources, flexible gas connectors have an expected product life of 10-15 years. However, as stated earlier, the useful life of the product may be considerably shortened if the connectors are subject to frequent flexing.

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UNITED STATES GOVERNMENT

Memorandum

U.S. CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, D.C. 20207

TO : Douglas Noble, Program Manager, EH
THROUGH: Nicholas Marchica, Project Manager, PSA
THROUGH: William H. King, Jr., Acting Div. Dir., ESES

DATE: May 7, 1982

FROM : Sidney H. Greenfeld, Technical Assistant, AED, ES

SUBJECT: Request Number 455, dated April 7, 1982, as Revised April 21, 1982, on Generic Flexible Gas Connectors

In the revised PSA request, Engineering Sciences was given an assignment on flexible gas connectors to:

1. Summarize and evaluate the model building code requirements.

2. Summarize and evaluate existing voluntary standards.

3. Summarize past CPSC engineering tasks.

4. Summarize AGA Special Announcements on the product.

5. What are the effects of contaminants on the product?

The attached report is Engineering Sciences' response to Request Number 455.

Attachment

RESTRICTED

GENERIC FLEXIBLE GAS CONNECTORS

NPI Request Number 455

Sidney H. Greenfeld

Directorate for Engineering Sciences
Consumer Product Safety Commission

May 7, 1982

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1. Summary and Evaluation of the Requirements for Flexible Gas Connectors in the Model Codes.

The four model building codes, which are the basis for the majority of state and local codes used in the United States, have similar requirements for listed flexible connectors for gas appliances. These connectors are designated as "approved" or as exceptions to a specified rigid connection. Following are brief summaries of these requirements:

CABO-Council of American Building Officials

One and Two Family Dwelling Units - Page 112, Section M-1910 Appliance Connectors.

Appliances shall be rigidly connected to gas piping (as set forth in M-1905) with an exception that approved listed metal appliance connectors conforming to Table 19-A (diameters and lengths) can be used, provided that

(1) Range connectors shall be less than 6 feet long

(2) Other appliance connectors shall be less than 3 feet long

(3) Connectors shall not be concealed or go through walls, floors, or partitions

(4) There shall be listed connector valves of not less than the same nominal bore as the connector immediately ahead of the connector.

SBCCI-Southern Building Code Congress International

Standard Gas Code-1980 & 81 Revision to 1979 Code - Pages 4-8, Section 403 Appliance Connections to house piping.

Appliances shall be connected to gas piping by:

(a) Rigid pipe or

(b) Listed appliance connectors in the same room as the appliance or

(c) Semi-rigid tubing up to six feet long in the same room as the appliance. Longer lengths are permitted with specific approval, or

(d) Listed quick disconnects

All gas appliances shall have accessible shut-off valves within six feet, upstream from the union or connector it serves and in the same room.

BOCA-Building Officials and Code Administrators

Basic Mechanical Code-1975 - Page 98 M-609.5 Flexible Connectors, M-609.5.1 Flexible Metal Tubing

The flexible connectors or tubing shall have an inside diameter equal to or larger than the appliance at the connection, shall be six feet long or less, shall be listed, shall have a shut-off valve at the connection with the gas supply pipe and shall not extend through any wall, partition, floor or ceiling.

ICBO - International Conference of Building Code Officials - 1979, Page 38, Sec 503(c) Type of Fuel and Fuel Connection

Gas appliances shall be connected to gas pipes through rigid connections, with the exception that approved listed semi-rigid or flexible metal tubing connectors may be used to connect a gas appliance, provided:

1. That the length of the connector not exceed three feet for all appliances but ranges and six feet for ranges.

2. An approved shutoff valve is installed between the connector and the gas supply.

3. That the connector not be concealed in or through a wall, floor or partition.

4. That the inside diameter of the connector be not less than the inside diameter of the connecting pipe on the appliance.

In addition to the four basic codes, there is a National Fuel Gas Code, approved by ANSI Committee Z223, which is designed to satisfy the immediate needs of the gas industry for a single installation code for gas appliances and equipment. This National Fuel Gas Code is designated as NFPA 54 or ANSI Z223. The latest version is the 1980 edition.

Page 47, Sec 5.5.1 Connecting Gas Equipment

Gas utilization equipment shall be connected to gas supply lines by one of the following:

(a) Rigid pipe

(b) Semi-rigid tube extensions of a tubing piping system

(c) Listed connectors that completely are in the same room as the equipment

(d) Semi-rigid tubing in lengths up to six feet that is completely in the same room as the equipment. Those may be longer if acceptable to the local authorities.

(e) Listed hose connectors in accordance with Sec 5.5.2.

(f) Commercial moveable equipment may use listed appliance connectors complying with ANSI Z21.69.

The connector or tubing shall be installed so that it is protected against physical and thermal damage. It is not meant for use under conditions of continual movement. Repeated flexing, bending or vibration should be avoided.

Aluminum alloy connectors and tubing shall be coated for corrosion protection where they may contact masonry, plaster or insulation or where they may be subjected to repeated wetting with water, detergents or sewage. They are not meant for outdoor usage.

All of these codes refer back to listed connectors, which means listed by the American Gas Association as complying with ANSI standards Z21.24 - 1973 (and revisions ... 24(a) - 1976, ..24(b) -1979 and revisions proposed on April 23, 1981): Metal Connectors for Gas Appliances, ANSI Z21.45 - 1979 and Z21.45(a) - 1981: Flexible Connectors of other than all metal construction for Gas Appliances. For LP gas, listed connectors also include those complying with UL Standard 569 - Connectors for LP Gas.

2. Summary and Evaluation of Existing Voluntary Standards

There are three major voluntary standards in use in the United States for flexible metal gas appliance connectors. These are:

- ANSI Z21.24 (1973), Z21.24a (1976) and Z21.24b (1979) - Metal Connectors for Gas Appliances
- ANSI Z21.45(1979) and Z21.45(a) (1981) - Flexible Connectors of Other than All Metal Construction for Gas Appliances
- UL 569 - Pigtails and Flexible Hose Connectors for LP Gas

The first two pertain to all natural, manufactured, mixed and LP-gases and LP-gas-air mixtures; the last, to LP-Gas.

All three standards define the materials of construction, dimensions, fittings, instructions for proper usage, marking and a series of performance tests for strength, corrosion resistance and recognition of fittings. The latter two, in addition, have tests for the performance and durability of the non-metallic surface of the tubing. For the purposes of this brief review, I will discuss only those portions of the standards related to failures of the fittings and corrosion of the tubing in the connectors. The standards are readily available for those interested in the construction details and other performance tests.

o ANSI Z21.24 (1973), Z21.24(a) (1976) and Z21.24(b) 1979) - Metal Connectors for Gas Appliances

The original draft standard for flexible metal tubing connectors was approved by Committee Z21 on October 22, 1941. A standard for semi-rigid tubing had been approved by ANSI (ASA then) on February 11, 1935. A consolidated standard was adopted on November 28, 1955. Later editions were adopted on July 27, 1960, December 26, 1963, and November 8, 1967. As a result of reported field corrosion problems, a revised standard with a corrosion test was approved on April 11, 1973. Addenda to this standard were approved on February 13, 1976 and August 20, 1979. Additional revisions were proposed on April 23, 1981, but not yet approved.

<u>Scope</u>: Newly produced assembled gas appliance connectors constructed of new, unused parts and materials and composed of semi-rigid metal tubing of sizes up to 1-1/8 in nominal outside diameter and having a fitting at each end provided with taper pipe threads, not exceeding 6 ft in length, for use at gas pressures not to exceed ½ psi. These connectors are considered suitable for use with natural, manufactured, mixed and LP-gases and LP gas-air mixtures.

This standard provides for use of flexible connectors with protective coatings as well as bare connectors. Where coatings are provided, they must cover all portions of the connector which are capable of being bent or flexed, must adhere tightly to the metal surfaces or not have any adverse effect on the performance of the connector. These coatings shall be self-extinguishing, as determined by a fire test in Sec 1.6.4.

This standard provides instructions for installation of the connectors and tests for leaks.

A test for stress corrosion is provided under Sec 2.8, in which the connector is deformed over a mandrel prior to exposure to ammonia vapors. Any protective coating is left on for this test only. Non-coated connectors are tested by a similar test in Sec 4.10. This test will produce failures in certain brass connectors at stress levels that might be introduced during installation or usage. Any larger stresses, such as might be introduced during the production process would also be detected here as well as in the mercurous nitrate test. Manufacturing stresses are usually relieved in the annealing process.

This standard permits soldered or brazed ferrules (ends) with retention skirts extending a minium of 1/8 in into or over the tubing. Brazing alloys must contain no phosphorus. It would be preferrable not to permit soldered or brazed ferrules. This standard also contains performance tests for bursting strength, torsion resistance, bending, high temperature resistance and fitting strength.

The provision for a larger solder or brazing surface and elimination of phosphorus from the brazing alloy should have coped adequately with the "Cobra" type failures. However, it is my understanding that soldered or brazed ferrules are no longer being used. The tubing ends are flared inside the connection fittings and the connector presents a single, homogeneous surface to the gas.

o ANSI Z21.45 (1979) and Z21.45a (1981) - Flexible Connectors of Other than All-Metal Construction for Gas Appliances

The origianl version of Z21.45 was approved by ANSI (then ASA) on September 18, 1964. Upon the reconstitution of ASA to ANSI, this standard was approved on April 14, 1971. The third addition, with revisions, was approved on August 20, 1979 and Z21.45a was approved in 1981. This latter revision pertained to the means for calculating the capacity of metal connectors.

Scope: This standard applies to newly produced connectors constructed entirely of unused parts and materials, consisting of flexible tubing dependent on other than all-metal construction for gastightness, of 1/4, 3/8, 1/2, 5/8, 3/4 and 1 in nominal inside diameter, and having a fitting at each end provided with standard taper pipe threads for connection to gas appliances and to house piping, not exceeding six ft in length.

This standard provides for materials of construction of fittings that shall be resistant to moisture and common household chemicals, but prohibits cast iron fittings. In specifying details of construction of the fittings to provide for tight connections, it requires the use of adapters between the connector and the tapered pipe threads used on house piping and the standard threads on appliances. This requirement attempts to avoid the leakage problems associated with attempts to use the machine threads of the connectors with the pipe threads of the house piping and many appliances. The standard also prohibits the use of gasket materials for gastightness because of their possible deterioration with time. Reuse of flexible connectors is prohibited because of the possible damaging of the seating and threads during disassembly and reassembly.

This standard provides for a protective coating on the outside of the connectors, which shall cover all portions of the connector capable of bending or flexing and requires that it be of a self-extinguishing material. A fire test is included.

Instructions are provided for attaching the connectors and testing them for leakage. Tests are provided for bursting strength and leakage under pressures up to 800 psi, bending 70 times over a mandrel of size related to the connector's diameter, torsion resistance (20 applications of 90^{o} twists), durability at 800^{o}F, capacity, season cracking, fitting strength, and ammoniacal stress corrosion. Permanent markings to identify the manufacturer and year of production are required.

This standard serves to answer the current needs for flexible metal connectors with linings or external coverings. However, there is no mention of soldered or brazed ends, which were the seat of one type of failure. It is possible that soldered or brazed ends might effectively be precluded by the acid treatments prior to and part of the season cracking test (Sec 2.6).

o UL 569 - Pigtails and Flexible Hose Connectors for LP-Gas - November 21, 1980.

This is the fifth edition, with the most recent revision dated April 17, 1981. Paragraphs 4.1, 14.1, 16.13, 16.14, 16.14, 22.1 and 22.2 went into effect on January 1, 1982.

Scope: Pigtails and flexible connectors intended for LP-Gas, for connection either to cylinders or between pieces of equipment, to be installed in accordance with NFPA 58, ANSI Z107.1.

Only the portions pertaining to pigtails will be discussed, for by definition, the flexible hoses are all non-metallic. Pigtails are defined as seamless tubing (usually copper) that has an outside diameter of 3/16 to 3/8 in, a length not exceeding 60 in and with end fittings, for use with pressures up to 250 psig.

This standard is primarily for soft-annealed copper tubing, but permits aluminum, brass and stainless tubing as well. However, for corrosion resistance purposes, it prohibits use of aluminum in combination with brass, copper or copper alloys. All brass components are required to pass a mercurous nitrate immersion test (Sec 19).

Cadmium and zinc plating are permitted and minimum thickness specified. Specifications for end fittings permit the use of brazing or soldering with materials melting above 1000 F; the specifications are those of other standards incorporated by reference.

In addition to the corrosion resistance test mentioned above, metal pigtails must past tests for aerostatic leakage, hydrostatic strength, tensile strength and bending.

Unless there are further revisions of which we are not aware, this standard has no provisions for corrosion resistance to ammonia for stresses acquired in use. The mercurous nitrate test usually does not detect these small stresses; it detects only major residual stresses, such as may be present from manufacturing if the post-forming annealing process were defective. However, because most of the pigtails made to this standard are soft-annealed copper, this omission may not be serious.

o Commentary on Standards:

The recent modifications of the ANSI and UL standards seem to be adequate for coping with the "cobra" type of failure and stresses that might be introduced into brass connectors through normal usage. However, major deformations through abrasive usage followed by exposure to ammoniacal atmospheres might produce hazardous situations in brass connectors that would comply with these standards.

RESTRICTED

3. Summary of Past CPSC Engineering Tasks

Following is a summary of the tasks associated with flexible metal gas appliance connectors in which Engineering has been involved:

- February, 1975 - Through NBS, analyzed the failure of a flexible brass gas appliance connector as having resulted from the ammoniacal leak testing fluid NBSIR 75-669 Failure of Flexible Brass Gas Appliance Connectors, Feb., 1975.

- January, 1977 - Phase I - Gas Appliance Connector Survey - 65 commercially available flexible gas connectors, representing 11 manufacturers, were examined for conformance with ANSI Z21.24. Those dated 1976 and later were examined under ANSI Z21.24(a).

- April, 1977 - Phase II Gas Appliance Connector Survey

  (1) Five connectors were tested for resistance to flexure cracking by ANSI Z21.24 Sec 4.3; all passed. (2) Four connectors were tested for resistance to season cracking by Sec 4.6 The brass connector failed, the stainless steel connector passed and the two epoxy-coated brass connectors failed. (3) Six connectors were subjected to the test for resistance to ammonia atmospheres in Sec 4.10. The two brass connectors and the damaged epoxy-coated brass connector failed. The stainless steel brass/aluminum and the undamaged epoxy-coated brass connector passed.

- November-December, 1979 - "Cobra" flexible metal connectors. Worked with CA and AGAL to notify gas companies of failure of brazed ends on a flexible brass appliance connector manufactured by Cobra Metal Hose Co., which is no longer in business. This action is continuing and is the subject of an AGA Special Announcement.

- July, 1981 - PSA Requests 192 & 193 - Failure of American Metal Products Corp. brass flexible gas connectors. Determined to be ammoniacal stress corrosion failures by Artech Corp.

- April, 1982 - Questions for use when investigating flexible metal gas appliance connectors.

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RESTRICTED

4. Summary of American Gas Association Special Announcements on Flexible Metal Connectors

There have been two Special Announcements on flexible metal connectors published in the Directory of the American Gas Association Laboratories in recent years. These are still appearing in the current issue, dated January 1, 1982.

The first, appearing on page XI, states:

"The Consumer Product Safety Commission has advised AGA regarding a potential safety problem in reference to a certain type corrugated metal hose. The problem brought to CPSC's attention concerns a gas connector with a button type end fitting brazed directly to the tubing. Our information indicates the unit was manufactured by Cobra Metal Hose in Chicago, Illinois from 1955-1964. Apparently, the brazed construction can deteriorate with age, and with movement or stress, the joint could break allowing gas to escape.

As of January 1, 1968, the ANSI Standard Z21.24 covering metal gas connectors was revised in an effort to prevent this situation.

The specific manufacturer, Cobra, is no longer in business. AGA has sent a special bulletin to all member utility companies advising them of the potential problem and suggesting that they initiate appropriate action in their service areas. If you desire further information, please contact your gas company."

The second Special Announcement appears on page XII. It states:

"The Laboratories have been informed by American Metal Products Co. (Div of Masco Corp.), Los Angeles, California, that [redacted] of their 3/8 in. size (Catalog No. 4G) coated appliance connectors of flexible metal tubing and fittings shipped between March 9 and April 17, 1979, and equipped with steel flare nuts, may have an improper flare seat angle which may cause the flared tubing to be weakened or sheared when the nut is tightened to the fitting.

The connectors may be identified by observing that the marked band bears the number "79" indicating year of manufacture, and are equipped with a steel flare nut with the following configuration:

(Drawing shows nut on the affected connectors with a tapered end toward the tubing and the unaffected connectors with a nut with a chamfered end toward the tubing)

American Metal Products Co., (Div. of Masco Corp.) has initiated a field recall program on these connectors. If any such connectors are encountered, it is requested that American Metal Products Co., (Div. of Masco Corp.) be contacted immediately."

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5. What are the Effects of Contaminants on the Product? RESTRICTED

Background

Over the years, there have been sporadic reports of corrosion failures of flexible metal connectors. In response to a request from ANSI Committee Z21, the AGA Laboratories conducted a survey in July 1972, among 33 major gas utility companies widely distributed throughout the United States. Twenty-three provided responses; twelve sent in flexible connectors. Based on this survey, it was estimated that there were over 30 million flexible metal connectors in use at that time, 18.5 million on ranges and 12 million on other appliances. Over the previous four years, approximately 0.3 percent were known to have failed.

Of 318 Field Failure Reports on their connectors, 288 connectors were sent to AGAL for analysis. Of these, 192 failed through cracking in corrugations, 92 through cracked or separations of ends and 21 through miscellaneous other causes. Essentially all the connectors (except 14) had been properly installed. These 14 evidenced physical abuse to the connector. The failures were on connectors ranging in age from less than one year (2) to over 12 years old (195).

The survey indicated that corrosion from external sources was the major problem, confirming the results of an earlier survey in 1966. Metallurgical examination indicated that the corrosion was related to exposure to ammonia vapors associated with low level stresses induced by handling and installation.

The AGAL recommended that:

(1) All single wall flexible connectors of copper based alloy be provided with non-metallic external coatings and comply with Section 4.10 of the current standard.

(2) Single wall connectors of non-copper alloy material shall also comply with the provisions of Section 4.10.

(3) All flexible metal connectors be of one piece construction.

(4) The season cracking test be retained to detect unrelieved manufacturing stresses.

Modifications in the ANSI standards as a result of their recommendations were discussed earlier.

Discussion

Flexible metal connectors used on gas appliances in homes may be subjected to any of a number of corrosive environments, both internally and externally. The corrosive contaminants in fuel gases are usually sulfur compounds found in "sour" gas in certain small, restricted parts of the country. Most natural and LP gas is refined prior to entry into gas pipelines or sale to consumers and is relatively benign. In areas where "sour" gas is sold, flexible connectors are either stainless steel or double walled, with the inner wall being made of aluminum. Internal corrosion is not considered to be a significant problem.

However, as shown in the 1972 survey, 192 of 318 connectors (about 60%) examined failed by cracking in the corrugations, presumably as a result of stress corrosion. Seventy-eight percent of the connectors replaced were on kitchen ranges, even though the survey showed only 60% of the connectors were used on kitchen ranges. Thus, the kitchen seems to be one of the more hostile environments for connectors. The most corrosive of the several agents to which the flexible metal connectors are exposed seems to be ammonia. It evaporates from such products as window cleaners, cleansers, wax removers, floor cleaners, waxes, dish washing materials. In addition to those products containing ammonia, there are also those containin amines, surfactants and quaternary ammonium compounds, such as oven cleaners, sizings and fabric softeners which may contribute to the problem. Some of these will also be used in the vicinity of dryers, in laundry rooms, and space heaters throughout the house.

The mechanisms by which brasses corrode in contact with ammonia, either in liquid or vapor form, are well understood.1/ Certain types of brass should not be used in a stressed condition in the presence of even intermittent low concentrations of ammonia.

Coating the connectors is frequently required in ammonia atmospheres; both PVC and epoxy coatings are used. However, neither has the elasticity required if there is much movement, particularly extension of the flexible connectors. Once the coating has been broken, corrosion progresses in the cracks.

Stainless steel flexible connectors are also made. For a while, it was felt that they might fail by chloride ion corrosion, for they may be exposed to table salt in the kitchen or household bleach (sodium hypochlorite) in the laundry room. However, we are not aware of any failures. Tests devised to expose stainless steel flexible connectors under stress to chloride corrosion at elevated temperatures have not produced failures. Stainless steel flexible connectors also pass the ammonia and season cracking tests.

1/ D.H. Thompson, Stress Corrosion Cracking of Metal. A State of the Art, STP 518, ASTM Philadelphis, Pa., 1972, and season cracking tests.

IV

LAMAR CONSULTANTS, INC.
531 Jefferson Street
Hinsdale, Illinois 60521
(312) 325-3400; 325-3400

August 11, 1982

CONFIDENTIAL

Mr. Douglas Noble
Office of Program Management
Room 426 B
U.S. Consumer Product Safety Commission
Washington, D.C. 20207

Dear Mr. Noble:

As we discussed on August 9, I am sending you the following items in relation to metal gas appliance connectors (commonly known as flexible connectors), and the work on standards for them, and some of their failure modes:

1. Lamar letter of April 2, 1982 regarding the failure of the flexible connector in Flint, Michigan.

2. Copies of six pages giving information from the Saginaw, Michigan fire department regarding 29 cases of gas appliance connectors rupturing at one end of the tubing.

3. Lamar letter to O.C. Davis dated 6/4/82 on the proposed AN standard for connectors for mobile homes.

4. Letter from Norman J. Latter to "Red" Davis dated June 15, 1982.

5. Lamar letter to Mr. Mattocks and Z21 committee - ANSI dated March 21, 1975.

6. Copy of results of survey of failed connectors conducted by AGA in the summer of 1972. (Cover letter is from O.C. Davis to members of Connector Subcommittee, dated October 4, 1972.)

In Item 1 above, the names of individuals involved have been deleted because litigation may still be pending. However, if there is specific information you want about the situation in Flint, I think I can get this released for you.

The situation in Saginaw seems far more extreme, and may be due to the triggering action of higher hydrogen sulfide concentration in the fuel gas there. Item 2 gives a great many details, and I am sure that Mr. Donald Couturier, Lieutenant in the Fire Prevention Bureau would be very interested to talk with you. The telephone number there is (517) 776-1383. I think it would be very interesting to know how many of the connectors which ruptured in Saginaw were made by [redacted] as opposed to the "Cobra" connectors which I understand were made by "D-K Manufacturing Company of Chicago" (no longer in existence).

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Item 3 in the list above is intended for review by Mr. Sidney Greenfeld in relation to Item 6 on the agenda of the subcommittee meeting on connectors, to be held in Cleveland on August 25-26. Item 4 is a letter from Mr. Norman Latter in relation to this. I plan to have dinner with Mr. Latter on the evening of August 24, about 6:30 p.m. and Mr. Greenfeld would be most welcome to join us if he will be in Cleveland by that time. I will plan to telephone your office on or about August 20 to learn about his plans.

Item 5 is intended to give you some of the background on my long campaign to get improvement in the standards for gas appliance connectors. Certainly there has been a great deal of opposition to this. When I see Mr. Greenfeld I will show him a copy of the letter I write to our attorneys early in October, 1975 because the president of one of the manufacturer companies was threatening to sue me and Harper-Wyman both, about my activities, which he said were "interfering with their business".

Item 6 gives detailed results of the survey on causes of field failures of 318 connectors including the following in Table II on page 3.

Reason for removal:

a)	Crack in corrugation:	192
b)	Crack in separation at end:	96
c	Bad Flare	8
d	Proper adapter not used	21

This report contains much detailed analysis and projections of failures on a national basis. It shows very serious problems. 149 of the 288 connectors sent to AGAL for examination showed stress corrosion, with 192 cracked in the convolutions. I am concerned that the subsequent changes in Standard Z21.24 (to add the moist ammonia atmosphere test, which in turn has required coatings on brass connectors) is not stringent enough. Work reported by Pat Thomas of CPSC shows that the coatings on connectors are often defective, allowing stress corrosion cracking to take place. Standard Z21.24 has no test specifications for adhesion of coating or its abrasion resistance or its completeness. It does not require straightening of the connector after the moist ammonia atmosphere test (a defective coating has been known to cause embrittlement of the connector so it failed when straightened.) The manufacturers have repeatedly voted down the proposal to straighten connectors after the ammonia atmosphere test.

As we discussed, I have a strong interest in improving the safety of connectors for gas appliances, and will be happy to work with you toward that end.

Sincerely,

Charles C. Lamar
President

P.S. Also enclosed is a brief summary of my activities during 45 years with Harper-Wyman Co. This includes a number of campaigns to improve standards for safety of gas appliances, of LP gas pressure regulators and of recreationa vehicles, in regard to both LP gas utilization and means of egress for occupants. CCL

~~CHARLES C. LAMAR,~~ CONSULTANT
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April 2, 1982

RE: FLEXIBLE CONNECTOR FAILURE -

Thank you for your letter of February 23 asking me to come and investigate the cause of fire in apartment, and for your letter of March 19, 1982, including copies of your letter of and copies of correspondence from the Saginaw, MI Fire Department detailing at least 29 cases of gas connector failure there. These latter cases seem definitely related to the subject fire, as they involve separation of brazed joints at the ends of convoluted brass tubing due to corrosion from within.

The brazing material used years ago to join the connector tube end to a ferrule is subject to gradual corrosive disintegration and failure when exposed to excessive sulphur compounds in fuel gases. There is a great deal of history of such failures with very serious results, as detailed in the attached listing of documents enclosed.

It is surprising to me that correspondence between of the Fire Prevention Bureau and Consumer Products Safety Commission indicates a lack of knowledge by CPSC of similar problems. Certainly, CPSC was fully aware of the problem in December, 1979 as evidenced by the enclosed letter dated December 14, 1979 to Mr. George Lawrence, President of American Gas Association, from Mr. Richard A. Gross, Executive Director of CPSC. This letter provided substantial details and requested AGA to notify gas utility companies of the problem and recommend corrective action, and this was done by Mr. Lawrence in his letter of December 19, 1979 to all member companies. Much more detail on this subject is given in the news article "Connectors May Be Fire Hazard" in the Denver Post dated February 21, 1980, per copy enclosed.

On March 17, 1982 I came to and went with you to the offices of the Fire Marshall, where we talked first with Captain , and later with Captain They allowed us to examine and photograph the connector which had been involved in the fire in apartment. The plated steel connector nut, which was still attached to a large manual shutoff valve (which had been removed from the gas supply piping), was found to have the following marking indented into its cylindrical surface: [redacted]" (No "date of manufacture" was found.)

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This company was acquired in 1966 by [redacted] (see letter dated March 29, 1982 from A.G.A. Laboratories, Mr. E.C. Calvert). This is now [redacted] Los Angeles, California, 90021, using the trade name [redacted] This may be of interest to your client because the liabilities as well as the assets would have been transferred to [redacted] which may have some responsibility in this matter. (See enclosed copy of AGA Directory listing for connection by [redacted]

On examination of the failed connector, it was apparent that the end of the convoluted brass tube had been joined to a ferrule by a brazed joint, and that this joint had failed, allowing separation and escape of gas, causing the fire in [redacted] apartment. In discussing the accident with Mr. he said the joint in question was partially separated and leaking gas, which was burning when he first came on the scene. After the fire was extinguished, he attemped to remove the connector intact, but it separated completely at this joint, resulting in the present condition. (I understand that no other source of gas leakage was found in other appliances or piping, so this joint failure was the sole source of the fire.) The brazing alloy surfaces are of a dull, grey-black, as would be expected with such a corrosion failure, subjected to elevated temperature.

During the last 20 years, there have been thousands of accidents caused by separation of such joints releasing copious amounts of fuel gas in homes, causing explosions and fires. The enclosed copy of a survey, conducted by American Gas Association and reported in a memorandum from S.L. Blachman to R.E. Cramer, dated 10/3/72, shows, at the middle of page 3, 96 failures with "crack or separation at end" of a total of 318 field failure reports during the 30 day survey. On page 5 of this report, the listing shows 79 of the 288 failed units returned had "End Fitting Solder Failure". On page 6, item 3 under "Recommendations" reads, "All flexible metal connectors be of one piece construction" so as to eliminate the hazard of brazed or soldered joints.

On page 2 of the survey, item 4 shows that the number of flexible metal connectors replaced by gas utilities due to failure, on a projected national basis would be 31,406 in 1971. Based on 96 of 318 failures reported due to crack or separation at the end, this would indicate 9,481 such failures per year nationally. Otherwise, based on 79 of 288 "end fitting solder failures" from actual examination, the projection would be 8,615 failures to this cause in 1971. However, the estimates for failure rates on page 2 of the survey show very rapidly increasing totals, almost doubling between 1968 and 1971, so failure rates were probably very much higher in 1981.

To illustrate the seriousness of such brazed joint separations, I am enclosing a copy of an article from Chicago Daily News for Tuesday, June 22, 1976, headed, "Evanston Explosion Injures Three". Shortly after this accident, I talked on the telephone with Mr. David Melzer, Fire Captain and later with Mr. Willard Thiel, Fire Chief. The failure had occurred at the brazed joint in a connector made by the Cobra Company, formerly of Chicago, which is long since out of business. You will note that Cobra is the brand name of the connector mentioned in the first paragraph of the CPSC letter to George Lawrence on this subject. Also, the NOTICE in the American Gas Association

Laboratories' "Directory of Certified Appliances and Accessories" for each issue beginning in January, 1980 points out that CPSC had advised AGA regarding potential safety problems in reference to certain type corrugated metal hose ---- made by "Cobra Metal Hose" of Chicago. This is the only manufacturer mentioned by either CPSC or AGA Laboratories in this context, although we know that other makers of connectors have had similar brazed joints and the same failure mode.

The explosion in Evanston caused the death of Mrs. Dorothy Hahn and injuries to Ruth Schuett and Charlotte McMahon. Another explosion in Skokie, Illinois, on July 7, 1974 caused severe injuries to Mr. Lam and blew out walls and floors of a large number of apartments, with damage estimated at $200,000, and injury to at least 8 other persons. (See Chicago Sun-Times article of July 8, 1974, "Nine Hurt in Skokie"). This accident was also due to failure of a brazed joint in a connector, as stated in the middle of page 4 in my letter to Mr. Mattocks and other members of Z21 Committee dated March 21, 1975.

Many other cases of explosion and/or fire have occurred in the area served by Southern California Gas Company. While I have no documentation about this, I understand this company has made a valiant effort to locate and replace connectors with such brazed joints. This effort has been dubbed "Operation Haystack", and has cost the gas utility more than three million dollars.

A change was made in the American National Standard Z21.24 covering such connectors, effective 1968, to prohibit the use of phosphorus in brazing alloys, with the idea of eliminating the cause in future brazed assemblies. Silver brazing alloys have been used for decades for joining parts of brass, copper, steel and many other materials. The best alloys for this purpose contain 45% to 50% silver, and thus are relatively expensive. Much cheaper brazing alloys contain either 15% silver and 5% phosphorous or 5% silver and 6% phosphorous. The Handy & Harmon Company provides both these alloys by their trade names, "Sil-Fos" and "Sil-Fos -5" respectively. In their "Technical Data Sheet #D-4", their statement about corrosion resistance reads as follows:

> "Normally the corrosion resistance of Sil-fos and Sil-fos -5 are of the same order as copper, but under certain conditions they corrode more rapidly. Sil-Fos or Sil-Fos -5 should not be used where the joints are exposed to sulphur compounds in gases or oils at temperatures above normal room temperature. As the corrosion by sulphur is cumulative, even very small percentages will eventually cause failure of the joint by disintegration." (Underlining added)

I understand the failure rate of phosphorized brazed joints is very much faster when the fuel gas contains relatively high percentages of sulfur compounds, such as hydrogen sulfide. This would seem to explain the very rapid failure in [redacted] where I understand gas with higher sulfur content had been introduced fairly recently.

As stated in the letter from Mr. Calvert of AGA Laboratories dated March 29, 1982, the 1963 edition of Standard Z21.24 did not prohibit phosphorous in brazing alloys, and this was prohibited for the first time in the addenda to the Standard Z21.24a in 1968. This date is the same as that mentioned in Mr. Lawrence's letter to gas companies dated December 19, 1979, and in the "Notice" in the AGA Directory, although neither of these documents mentioned phosphorus or the correlation of sulfur in the gas.

Even if the brazing alloy contains no phosphorus, there is still concern about the likelihood of failure of brazed joints because they are so dependent on brazing temperature, on cleanliness, on operator technique, on materials and on destructive testing. Certainly we hear of brazed joint separations in connector assemblies made long after the effective date on which phosphorous was prohibited. This is why you see letters in my files dated 1976, 1977 and 1980 from Northern Illinois Gas Company and from Pacific Gas and Electric Company to the sub-committee on standards requesting a change in the standard to prohibit <u>any</u> brazed or soldered joints in flexible gas connectors. This was always voted down by the manufacturer members. In other letters, as written by Tom Croddy of Ni-Gas, and by me, it was recommended that the standard be changed to require a mechanical joint of certain strength and gas tightness be made <u>before</u> sealing by a brazed joint. This also was voted down by manufacturers, even though very few connectors are made by brazing these days. (About 95% of connectors are made with integral flared fitting.)

In conclusion, it is my opinion that the accident in [redacted] apartment resulting from release of unburned gas by failure of the [redacted] connector, was not due to any fault of hers. (I understand the range and its connector had not been moved for 3 years according to statements by her and by the building maintenance man.) Instead, the cause of the accident appears to be with a faulty brazed joint in the connector, and probable chemical attack of the brazing alloy by sulfur compounds in the fuel gas.

Regarding sulfur compounds in natural gas and their removal, the Gas Engineers' Handbook has a section of about 10 pages on this. Page 4/86 is enclosed, showing that some gas fields can contain up to 46% by volume of sulfur compounds, mostly hydrogen sulfide. Procedures for removal of hydrogen sulfide and carbon dioxide are described in this Chapter 9, which I can copy and send, if you like. The opening paragraph on page 4/86 states, "For good distribution practice, total sulfur content below one grain per 100 cubic feet is desireable". I would be quite interested to know what has been the maximum sulfur content of gas distributed in both the Saginaw and Flint systems in the last five years.

In an effort to learn the age of the connector, I showed your photographs of the gas range (installed at the same time) to a number of knowledgeable people at meetings I attended last week. None of them could say with certainty who the maker was, but they thought the range was at least 20 years old. Were you able to find the range, or any record of the make, model and serial number from its "AGA Rating Plate"?

As we discussed, I would be interested to know what other makes of connectors in Saginaw have shown failure of the brazed joints, along with the dates on the aluminum rings on the connectors. This would be helpful in relation to future work on Standard Z21.24.

One question which may be important is whether the [redacted] Gas Company in [redacted] did issue a "bill-stuffer" to all customers in 1980, warning of the possible failure of connectors made prior to 1968 with the brazed construction, as recommended by CPSC and covered in the letter from Mr. Lawrence. If not, they may have some liability in this matter, along with U.S. Brass.

I would be glad to learn your reaction on matters covered in this report. Please let me know if further information is needed, or if I should consider my work completed.

Sincerely,

Charles C. Lamar

Charles C. Lamar, Consultant
Member, Subcommittee on AN Standard
for Gas Appliance Connectors, Representing National LP Gas Assn.

CCL:db
Enclosures

P.S. You had asked about the toxicity of hydrogen sulfide, and an excerpt is enclosed from "Dangerous Properties of Industrial Materials" by K. Irving Sax (Reinbold). H_2S is <u>very</u> toxic. (Only 20 ppm allowed for 8 hr exposure by ACGIH.) 1% in air can cause death in 30 minutes. Higher concentration can cause death quickly, even "immediately" due to paralysis of the respiratory center. This explains the death you mentioned at a gas well in Michigan with high H_2S in the gas.

PPS- A specification of U.S. Dept. of Transportation states that copper pipe or tubing shall not be used as fuel gas conduit if the H_2S content of the gas exceeds 0.3 grain per 100 cubic feet.

CCL