Draft Minority Report to "Improving natural gas safety in earthquakes,"

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For the ASCE-25 Task Committee on Earthquake Safety Issues for Gas Systems

and the California Seismic Safety Commission

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I appreciate the opportunity of serving as a Member of the ASCE-25 Task Committee on Earthquake Safety Issues for Gas Systems. Ours was a consensus committee in the sense that efforts were made to achieve a consensus among the members on the wording of the Committee's reports, which include a 1-page insert for the Seismic Safety Commission's (SSC's) "Homeowners' guide to earthquake safety," and a 40—50 page report.

However, as is often the case with consensus committees, there was considerable disagreement on many of the issues that were raised. It is traditional in such cases for those in the minority to express their disagreements in a minority report, which is published at the end of the report that was approved by the majority.

The Forward to this minority report—submitted as a letter to the SSC on June 26, 2002—summarizes my deep concerns about the majority report and the insert to the homeowners' guide.

This is a first draft of the minority report. It is my intention to revise it following the Hearing on July 11th, which will give me an opportunity to correct any errors, incorporate any additional comments raised during the Hearing that I believe should be included, and consider any suggestions that are made that might improve the document. If the majority report is revised, I may find it appropriate to delete certain sections of the minority report. During the editing process, I will do my best to shorten the minority report, and will put the main body of the text and the references into the same format as in the majority report. I trust that the Commissioners will appreciate that this draft minority report is being prepared in haste to meet a submittal deadline of noon on July 10, 2002.

Introduction

This Task Committee was an excellent opportunity to discuss and evaluate various aspects of seismic gas safety. The majority report is a valuable contribution to public safety as it addresses many important issues and will help to educate the public about many of the risks associated with gas during and following earthquakes. However, anyone who has been following the ongoing debate over the past 20 years between those who believe it is important to mandate the installation of seismic gas shutoff valves (SGSVs) and those who feel it is not will quickly recognize that the report is strongly biased toward the position of those who oppose mandation.

This is not surprising as our Committee's primary financial sponsors are the two largest natural gas utilities in California, who have been opposing efforts to mandate the installation of SGSVs for at least 20 years.

Although called a consensus committee, ours was not a true consensus committee because membership was not open to anyone who expressed an interest in becoming a member. Instead, members were selected in secret by a Planning Committee, which included an employee of a sponsoring gas utility and the Committee's Consultant. Prior to being invited to join the Task Committee, several Task Committee members or the organization they represented were on record as opposing the mandation of SGSVs.

Although our Committee may be balanced in terms of professions, it is not balanced in terms of those who favor and those who oppose mandation of SGSVs. Our Committee was stocked with persons opposed to the mandation of SGSVs, while an effort was made to block the potential membership of persons who may have supported the concept of mandation. For example, Dr. Charles Scawthorn, who is widely recognized as the world's foremost expert on the subject of fire following earthquake, was not invited to be a member. Instead, a professor who was recently a paid consultant to PG&E was invited. Also, neither the Los Angeles Fire Department (LAFD) nor the

San Francisco Fire Department were invited to have a Member. The omission of the LAFD is particularly significant because Los Angeles enacted an ordinance in 1995 that mandates the installation of SGSVs; and has twice taken action to increase or strengthen its mandate. Representatives of the LAFD have testified before the Seismic Safety Commission on at least two occasions about the necessity of mandating SGSVs—Fire Chief Frank Borden following the 1987 Whittier-Narrows earthquake (SSC, 1988), and Fire Marshal Davis Parsons following the 1994 Northridge earthquake (SSC and PUC Utilities Safety Branch, 1994).

About two weeks before our first meeting, we were sent a draft report. The same person who wrote the first draft also managed all four of our meetings. It was well known before our first meeting that the person hired to be our Committee's Consultant is strongly biased against the mandation of SGSVs (see for example Honegger, 1998, pp. 478 and 487). Throughout our proceedings, our Committee's Consultant often functioned as though he were being paid directly by the gas utilities that were sponsoring our Committee. He often interrupted me and fellow Committee Member Jim McGill with statements such as "I know where you're going with that," "We've already decided not to discuss that issue," or "That's not within the scope of this Committee." After submitting my 2nd ballot, our Committee's Consultant tried to persuade me to withdraw my negative votes, suggested revisions, and supporting comments. He questioned the wisdom of my criticism of portions of a report co-authored by fellow Committee Member Prof. Brady Williamson—a report that was funded by a sponsoring gas utility and edited several times by a gas-utility employee who was on the Planning Committee and was also an Alternate Member. The Committee's Consultant made it difficult to impossible for my suggested revisions to be discussed during the meetings by allocating most of the meeting time for discussions of his favorite issues and little or no time to discuss mine—justifying his actions on the basis that he needed to establish a time schedule for the meetings. He engendered a polarized atmosphere by recommending to other Committee Members before our 3rd meeting that they should reject most of the revisions I'd suggested. When we did discuss issues I had raised, the Committee's Consultant almost invariably defended the draft as he had written it. It is a clear case of mismanagement that the author of the first draft was the same person who controlled the discussions and decided which comments to include and which to ignore in subsequent drafts. Our Committee was also mismanaged in that votes were seldom taken on contentious issues, and many decisions were made without a quorum.

The process we went through made it clear that there are two different camps on the issue of seismic gas safety. One side believes that mandating the installation of SGSVs is essential to minimizing the risk of post-earthquake conflagrations. I believe that most knowledgeable people belong to this camp. The other side believes that installing SGSVs is unnecessary and too expensive.

I became involved with seismic gas safety in 1985 after reading a newspaper article addressing a SGSV manufacturer's disagreement with the arguments made in a gas utility's position paper opposing adoption of local ordinances that would mandate the installation of SGSVs. That position paper (SoCalGas, 1983) argued that the danger of gas leaks following earthquakes was overstated, and that widespread use of SGSVs would unnecessarily interrupt natural-gas service to many homes and businesses without significantly increasing public safety; it also falsely stated that there was no record of homes or businesses burning following the 1971 San Fernando earthquake. The SGSV manufacturer provided the reporter with clippings that reported fires had occurred following the 1933 Long Beach and 1971 San Fernando earthquakes, but as the reporter noted, the 1933 and 1971 data he received did not mention the causes of those fires. His article concluded "...the jury is still out on automatic gas shutoff valves. We're all on that jury and need more evidence from both sides" (Cherniss, 1985).

I researched the topic for the SGSV manufacturer, and soon discovered that gas leaks had caused numerous fires following earthquakes. Besides the hundreds or perhaps thousands who died due to the fires that followed the 1906 San Francisco earthquake, I discovered that two Californians had died due to gas leaks following the 1952 Arvin-Tehachapi and 1955 Concord earthquakes, and that numerous homes and businesses had burned or exploded as a result of earthquake-related gas leaks. I presented my findings in speeches to engineering and safety societies throughout California, including a presentation to the 1987 Highrise Life Safety Symposium two days before the 1987 Whittier Narrows earthquake (Strand, 1987). I expanded the results of my research into a longer report, which was perhaps the first effort to document the performance of SGSVs during numerous earthquakes (Strand, 1988); my report also catalogs gas fires and explosions due to earthquakes and summarizes and refutes the arguments made in three gas-utility position papers (SoCalGas, 1983; 1987; & 1988):

1) SGSVs can actuate under aseismic conditions;

2) SGSVs actuate whenever the predetermined vibration level is reached;

3) Many customers would be needlessly inconvenienced;

4) Unqualified persons relighting pilot lights could create a potentially hazardous situation;

5) Some SGSVs with unrestricted access could be tripped by vandals and reset without relighting extinguished pilots lights, thus increasing the risk of explosion;

6) Temporary lack of gas for heating, sterilizing water, and cooking food could impair the health of infants, the elderly, the infirm and others, especially during cold winter months;

7) The Long Beach and Los Angeles Unified School Districts had discontinued the use of SGSVs;

8) Resources needed to effect widespread installation of SGSVs might be better spent in other ways;

9) Some gas leaks discovered after earthquakes may have already existed; and

10) Some persons feel that there isn't enough convincing data that mandating the installation of SGSVs is necessary to prevent gas-caused fires following earthquakes.

The majority report touches upon most of the above themes, and downplays the threat of gas-related fires following earthquakes at every turn. It also only addresses natural gas systems, even though propane gas is widely used throughout the State. I believe that far-minded persons, after reading this minority report, will conclude that there is a serious risk of fire following earthquake, and that mandating the installation of SGSVs would provide important safety benefits to individuals and communities.

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3.2 The Gas Delivery System

After an occupancy permit has been issued for a building, the natural gas utility installs its meter set assembly (MSA) and connects the service tee that defines the terminus of the MSA to the customer line. A plumbing inspector does not inspect the piping installed by the gas utility to connect its MSA to the approved customer line because it is owned by the utility and is not under the jurisdiction of the local building and safety department.

The gas utility's point of delivery has been defined as:

> "the outlet fitting of the meter installed by the utility or the point where the pipe is owned and installed by the utility connects to customer owned piping, whichever is further downstream" (California Public Utility Commission General Order 58-A, § 22[a]); and

> "(1) a customer meter or the connection to a customer's piping, whichever is further downstream, or (2) the connection to a customer's piping if there is no customer meter." (49 C.F.R. § 192.3)

In the case of a ¾" customer line served by an MSA with a ¾" post-meter service tee, it may be difficult to distinguish which piping between the service tee and the building was installed by the utility. But in the case of buildings with larger customer gas lines, it is usually much easier to determine the utility/customer interface, because the point where the line increases in size to meet the sizing requirements of the Uniform Plumbing Code (UPC) (and assure that the UPC's pressure-loss allowance is not exceeded) almost always marks the terminus of the utility's pipeline and the beginning of the customer line. There are, of course, exceptions. Some customer lines or customer/utility interfaces have been modified in such a way that the customer/utility interface is not clear.

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4.0 Natural Gas Performance in Past Earthquakes

It would be foolish to allow ourselves to be misled into thinking that the absence of conflagrations following three recent moderate-sized California earthquakes is indicative of what the role of natural gas will be during future California earthquakes. As noted following the 1971 San Fernando earthquake:

> "Fortunately, in past earthquakes, extensive structural fires attributable to natural gas leaks have not occurred, but this does not mean that a problem does not exist." (Algermissen and others , 1973, p. 268)
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> "The possibility of a 'fire storm' (e.g., Hamburg, Germany during World War II) [in the Greater Los Angeles Area] has been considered with regard to the many industrial areas and to widespread residential districts of wood frame construction. Although deemed improbable because of existing fire breaks and spacing of building groups, such a fire condition following severe earthquake must not be completely discounted in the event of Santa Ana wind conditions." (Algermissen and others, 1973, p. 317)

The data presented in the majority report must be tempered with the realization that fortuitous conditions following the 1987 Whittier, 1989 Loma Prieta, and 1994 Northridge earthquakes were instrumental in limiting gas-related casualties or property damage. A far greater number of ignitions (gas-related and otherwise) would certainly have occurred during each of the three moderate-sized earthquakes discussed in the report if they had occurred in the middle of a business day; and the result of those fires would have been amplified if there had been strong wind conditions. The majority report is full of wishful thinking when it states that it is unlikely that more than one negative condition will be present when earthquakes occur. We should be in earnest preparation for much larger earthquakes occurring during far less fortuitous circumstances. In other words, we should expect Murphy's Law to come into play, and prepare accordingly for the worst-case scenario!

Other factors besides those listed in the majority report that can exacerbate the post-earthquake fire risk are countless reports of gas odors, injuries or casualties sustained by firefighters, the inability to refuel firefighting vehicles due to loss of electricity to fuel pumps, or flat tires on firefighting apparatus due to running over broken brick glass, or nails. Every firetruck in town had a flat tire in 45 minutes following the 1983 Coalinga earthquake.

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4.1 1906 San Francisco Earthquake

Winds were noticeably absent when the 1906 San Francisco earthquake occurred, and yet 60% of the built city burned within the next 3—4 days. Recent studies have concluded that over 2000 persons may have died due to the earthquake and fire (Hansen and Condon, 1989).

Once a conflagration gets started, it can generate its own winds. The fires the followed the Magnitude 7.8, September 1, 1923, Great Kanto, Japan, earthquake burned approximately 3 times the area that burned following the 1906 San Francisco earthquake, and were believed responsible for approximately 100,000 of the estimated 140,000 deaths (Japan Bureau of Social Affairs, 1926).

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4.2 January 17, 1994, Northridge, California, Earthquake

The fire-incident data for the 1994 Northridge earthquake is underestimated, partly because fires reported on one incident report may have burned multiple structures. Fires at several mobile home parks are reported on one incident report at the same address, even though there were multiple ignitions and numerous dwellings were burned (Scawthorn, 1996).

Because of the unusually high number of incidents reported (2,332 during the first 27-1/2 hours, which greatly exceeded the average of 900 incidents in a 24-hour period), some incidents were not reported. Also, the dispatch center reduced the number and types of incidents that it dispatched resources to. Eleven minutes following the earthquake, assignments were degraded to the disaster mode, in which resources are not assigned to 13 categories of incidents. The LAFD concluded that 158 structure fires occurred during the first 27-1/2 hours, not counting all the multiple fires that occurred at mobile home parks (e.g., 58 mobile homes burned at one park, 22 at another, and 54 at another) (Borden, 1996).

It is fortunate that there were numerous backyard swimming pools in areas of the San Fernando Valley where the firefighting water supply failed. Besides drafting water from pools, the fire department used helicopters to drop over 15,000 gallons of water on some burning structures (Borden, 1996).

SoCalGas restored 119,600 out of 151,000 service outages within about 2 weeks. Of the 31,400 services that it had not restored, 9,100 could not be restored due to structural damage, and the other 22,300 were waiting for the customer to return home or a determination to be made that the building was structurally safe. SoCalGas testified that restoring gas is labor intensive because "you have to look and make sure that the appliances haven't shifted…" (Assembly Committee on Utilities and Commerce, 1994).

If the Northridge earthquake had occurred during the middle of a business day, instead of at 4:31 AM on a federal holiday, most persons would not have been home to immediately shut off the gas supply to their home and their neighbors', and there certainly would have been many more gas-related and other types of ignitions. If there had been a Santa Ana wind condition, all the ingredients for a conflagration would have been present.

It is fortunate that the earthquake occurred in winter, when the humidity was relatively high; the wind conditions were light; the electrical system for the entire city went down immediately following the mainshock; the epicenter was near the margin of the urban area; the fire department was well prepared; and the aftershocks were not heavy. It is also fortunate that this earthquake was of moderate size.

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4.3 October 17, 1989, Loma Prieta, California, Earthquake

The fire that consumed a collapsed apartment building in the Marina District—in which a woman perished—could easily have spread throughout the Marina District if strong winds had been present at the time of the earthquake. Everyone remembers seeing the vertical column of black smoke photographed by the blimp diverted from the cancelled World Series game. Smoke doesn't form a vertical column like that when there's wind. It's fortunate that a fireboat was available, the fire was close enough to the harbor for a line to reach it, and there weren't any other nearby fires, because no firefighting water was available from the severely damaged water-distribution system.

It is fortunate that most people had arrived home early to watch the World Series, which featured both of the local teams, so they were able to shut off their gas if they detected or suspected a leak. There would have been many more gas-related fires if the earthquake had occurred during business hours, or if the electrical system had not gone down for hours in much of the heavily shaken area.

In Santa Cruz, the 9-1-1 system was overwhelmed with calls reporting gas leaks and gas odors.

The San Francisco Fire Marshal testified before the SSC that gas fires were posing a serious threat in the Marina District and "it was lucky that the gas problem was handled quickly before a fire storm situation developed and spread out of control." (National Academy of Sciences, 1994, "Practical lessons from the Loma Prieta earthquake," p. 89)

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4.4 October 1, 1987, Whittier, California, Earthquake

The Los Angeles Fire Department was overwhelmed with calls for assistance, including many to report gas leaks or gas odors. There was a Magnitude 5.3 aftershock on October 4th, about 2-1/2 days later. Together, these earthquakes caused about $333M in insured losses.

The primary reason that the 1987 Whittier earthquake did not cause more gas-related fires is because of prompt manual shut-offs of individual gas services by residents, neighbors, firemen, and gas-utility personnel. Besides the 3 gas-caused fires reported by the Los Angeles Fire Department (LAFD), another 6 were reported by the Los Angeles County Fire Department, 1 by the Alhambra Fire Department, 2 by the Downey Fire Department, and 1 (possibly 2) by the El Monte Fire Department (Strand, 1988). The LAFD was taxed to the limit by the number of calls requesting assistance; responding to at least 242 reported natural gas leaks from the time of the mainshock through October 4, and shutting off at least 72 gas services as a result of those calls.

Both the Los Angeles and Los Angeles County Fire Departments believe their reported figures were underestimated because they gave advice to many persons over the phone and many incidents were not assigned incident numbers due to the high work load and busy communication channels.

What if the Superstition Hills, California, earthquakes of November 23 and 24, 1987, had occurred in Whittier? In that sequence, a Magnitude 6.4 earthquake was followed less than 12 hours later by a Magnitude 6.7 earthquake. Most people do not expect a damaging earthquake to be followed by an even stronger one.

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4.5 Rate of Occurrence of Gas-related Fires in Other Earthquakes

<u>Magnitude 6.3, March 10, 1933, Long Beach earthquake</u>: This earthquake caused numerous gas leaks and gas-related fires. There were so many gas-related fires in science or chemistry school buildings that the State mandated the installation of SGSVs in public schools (Strand, 1988). The exact number of fires is unknown, because many were not reported. Seven of the nineteen reported fires in Long Beach were attributed to leaking gas (Neumann, 1935). Yet it has been reported elsewhere that about 20 fires were burning at midnight (about 6 hours following the earthquake) and fires continued to occur throughout the next day (Du Ree, 1941). It is fortunate that wind was absent or negligible (Neumann, 1935), because by midnight, firefighting activities and leakage from about 50 damaged water lines had depleted the city's water supply to 4% of capacity (Porter, 1934).

The Gas Superintendent of the Long Beach Gas Department directed citizens over the radio to shut off their own gas service, and engineering personnel promptly shut off the main valves to the distribution system within two hours, which no doubt prevented countless gas-related fires. The Long Beach Gas Department had learned valuable lessons from the Magnitude 6.3, June 29, 1925, Santa Barbara earthquake, during which prompt action to shut off the gas distribution system was credited for saving Santa Barbara from conflagration, along with prompt shut off of the city's electricity. As was the case following the 1925 Santa Barbara earthquake, every gas service in Long Beach was closed for safety precautions, and public warnings were issued prohibiting tampering with gas meters or turning on the gas until the gas man had inspected the system and restored the service. Thirty percent of all the gas services in Long Beach required second or third inspections before service could be restored (Long Beach Press-Telegram, n.d.).

Magnitude 7.7, July 21, 1952, Arvin-Tehachapi earthquake: This earthquake and its aftershocks caused several gas fires and explosions. Following the mainshock on July 21st, a man in Arvin died from the burns he suffered when his gas stove exploded (Murphy and Cloud, 1952), a Bakersfield home exploded due to leaking gas (Anonymous, 1952a), and an explosion was reported inside a Bakersfield automobile agency (Los Angeles Times, July 21, 1952). In Tehachapi, service was shut off at the main to 18 businesses in the downtown area, and 200 customers turned off their own gas (Newby, 1954). The Magnitude 6.1 aftershock of July 28, 1952, caused ten or more fires in the Bakersfield area, some of which may have been caused by leaking gas, including one home that burned down (Murphy and Cloud, 1954).

Magnitude 5.4, October 23, 1955, Concord, California, earthquake: This earthquake cracked a gas line in an apartment building in Oakland, which caused an explosion and fire in which an elderly woman burned to death (USC&GS, 1956; Coffman and von Hake, 1973a).

Magnitude 9.2, March 27, 1964, Alaska earthquake: The area most heavily shaken by this earthquake was sparsely inhabited. The natural gas system in Anchorage was less than 4 years old, yet suffered extensive damage. It is fortunate that landslides and ground settlements ruptured the gas distribution lines in many places, which had essentially the same effect as if there had been numerous SGSVs and certainly prevented numerous gas-related fires. It is also fortunate that the electrical system failed immediately, as there was no water supply for fighting fires.

February 9, 1971, San Fernando, California, earthquake: Following the mainshock, 20 fires due to leaking gas resulted in structural damage or injuries to people (Strand, 1988). The day after the earthquake, a gas explosion in a Westwood Village office building injured 10 persons, including major injuries to two gas-company employees and a fire captain (Los Angeles Times, February 11, 1971). Seven days after the earthquake, 3 persons were injured by a gas explosion in a Los Angeles apartment, including an 81-year-old man who was blown 21 m (70 feet) across the street and suffered serious burns over 70% of his body (Los Angeles Times, February 17, 1971).

Fifteen persons were treated in area hospitals for burns of unspecified origin (Olson, 1973). Two firemen were injured fighting a gas-caused dwelling fire in Solemint (Aroni, 1973). As was the case in Anchorage following the 1964 Alaska earthquake, ground movements broke up the gas distribution system in Sylmar, which prevented many gas-related structure fires. The LA Fire Department responded to 456 alarms for fire during the first 8 hours, of which 128 were actually fires (Los Angeles County Earthquake Commission, 1975).

Emergency service personnel responded to many reported gas leaks, apparently shutting off the gas service to many of them just in time to avoid additional explosions or fires (Simms, n.d.). The gas company turned off the gas service at each home in the damaged area (Los Angeles Times, February 10, 1971, part 1, p. 1).

Due to serious damage to the Van Norman Dam, about 80,000 residents were evacuated. About 5800 of them turned off their gas before leaving.

Ten days following the earthquake, winds in the epicentral region gusted up to 50 mph; also, service was shut off to about 9700 customers in the Sunland and Tujunga because of low pressure in the main caused by the clogging of three pressure regulators in an 8” main.

Magnitude 6.3, May 2, 1983, Coalinga, California, earthquake: It was reported that while firemen were preventing fires by shutting off gas services all over the city, crews from the gas utility were busy turning on the gas lines the firemen had turned off (Brown, 1984).

Magnitude 5.6, July 8, 1986, North Palm Springs, California, earthquake: This earthquake caused a gas fire in a dwelling near Idyllwild when propane gas leaking slowly from a loosened connector to a waterheater was ignited.

Magnitude 6.9, April 25, 1992, Petrolia, California, earthquake: The Scotia Shopping Center and the post office and grocery store in Petrolia burned down. A fireman fighting the Scotia fire was injured by smoke inhalation. The post-office fire damaged a wall of the Petrolia firehouse. A small fire occurred in Loleta. Another small fire occurred in Ferndale, where the volunteer fire department immediately shut off all propane gas services in the downtown area. Concerned that they would be unable to stop even a small fire from spreading through the damaged buildings, Ferndale's volunteer firemen checked the gas services twice daily for four days to make sure that they remained off. PG&E announced that they were sending 60 trucks to help restore gas to 500 customers, many of whom had shut off the gas at the meter. Emergency bulletins noted that PG&E discourages the practice of turning off the gas unless there is a smell of gas, but also noted "there is a concern of fire with turning the gas back on" (OES, 1992).

<u>Magnitude 7.3, June 28, 1992, Landers, California, earthquake:</u> This earthquake caused numerous gas leaks and several gas-related fires in a sparsely populated area. Both fires that completely burned down homes in Landers were believed to have been caused by gas leaks. Gas leaks were also believed responsible for the two mobile home fires in Yucca Valley, one of which was a complete loss. The earthquake also ruptured a gas line in a market along Big Bear Boulevard that caught fire (EQE, 1992).

<u>Magnitude 6.5, June 28, 1992, Big Bear Lake earthquake:</u> Ten of the 12 residential fires reported following this earthquake were attributed by fire districts to natural gas or propane leaks ignited by pilot lights on waterheaters (Levenson, 1992). The gas valves were shut off at many vacation homes, and many persons manually turned off their gas as well as their neighbors, which may have prevented many fires since there were about 100 gas leaks in Big Bear City. The natural gas utility performed meter-clock tests, and locked all services that did not pass the test until a plumber had completed the necessary repairs and certified that the piping was tight.

<u>1995 Kobe, Japan, earthquake:</u> Among the valuable lessons that can be learned from the aftermath of the 1995 Kobe earthquake is the need to promptly shut off the gas-distribution system following earthquakes to areas where it is known that there are numerous fires. It has been reported that it took over 5 hours for the Osaka Gas Company to make the decision to shut off its system in Kobe, despite widespread TV coverage of numerous fires throughout the city. With more than 2000 breaks in the water distribution system, the Kobe Fire Department was without a firefighting water supply within a few hours and had difficulty obtaining water by relay or tanker trucks (Scawthorn, 1996).

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4.6 Summary of Earthquake Experience

The majority report suggests that the absence of conflagrations and widespread gas fires following three moderate-sized California earthquakes that occurred from 1987—1994 means that this cannot happen in the aftermath of future earthquakes in the United States. It fails to note that conflagrations may have occurred if most people had been away from home or there had been strong winds.

We must not allow ourselves to be lulled into complacency just because 3 generations of Californians have been fortunate the past 96 years:

> "It must be recognized that earthquakes of more than moderate magnitude may occur at any time in this region, that a severe conflagration might follow such an earthquake, and that as a result the damage might be increased ten-fold." (Joint Technical Committee on Earthquake Protection, 1933)

> "The potential exists for large conflagrations following a major earthquake in an urban area. Under adverse meteorological and other conditions, these conflagrations may burn for several days, replicating the events of 1906 in San Francisco and 1923 in Tokyo." (Scawthorn, 1996)

In general, the more leaks that occur, and the smaller the percentage of persons who are at home, the more gas-related fires that can be expected to occur; and the stronger the winds, the more likely it is that some of those fires will spread and evolve into deadly conflagrations.

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6.1 Gas Leakage

The amount of gas leakage also depends on the nominal size of the damaged piping or other system component(s).

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6.2 Interruption to Natural Gas Service

This section suggests that the primary consequence of an earthquake is unnecessary gas shutoffs; and not the potential hazard of gas-related fires. There are many reasons for interruption of gas service other than people turning off their gas after observing a leak or as a precaution because natural gas leaks are far more likely to occur during earthquakes. Some of the restoration delays may be due to the lack of electricity needed to operate the gas distribution system, extensive damage to the gas distribution piping or equipment such as compressors and odorizers, or extensive damage to the water distribution system. Following the 1906 San Francisco earthquake, gas service restoration to buildings in the unburnt district was delayed 10 days until repairs were completed to the water distribution system.

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6.3 Business Interruption

It is the fires following earthquakes, and the resultant loss of life and property, grief and suffering, and direct and indirect social and economic losses that can linger for years and even decades—not the rapid shutoff (automatic or otherwise) of the gas supply into distribution lines and customer lines—that can cause the sort of widespread and prolonged business interruption that we should be focusing on preventing.

Failing to shut off the gas in time can prove catastrophic. Throughout modern history, whenever conflagrations have occurred following earthquakes, they have often caused as many or more casualties, loss of property, and business interruption than was caused by the strong ground shaking. The death and destruction caused by conflagrations following earthquakes can lead to business interruption measurable in years and decades, which would affect not only the communities impacted by the strong ground shaking, but also the surrounding region and the entire State. Since California is the most populated State in the U.S. and its top economic engine, a conflagration in any major California city would also impact the U.S. economy. And since the U.S. economy is the strongest in the world, an urban conflagration in a large California city could also impact the global economy.

There are also serious insurance and reinsurance issues that would impact business interruption and which remain to be properly addressed, because many insurers and reinsurers may become insolvent or unable to issue new insurance for any concern for an indefinite period should a conflagration strike a major California city.

One way to minimize the potential for this type of catastrophic business interruption is to mandate the installation of SGSVs. Mandating the installation of seismic shutoff switches for residential service would also help to reduce the risk.

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6.4 Temporary Relocation

Natural gas has been labeled as the fuel for survival following major earthquakes (SoCalGas, 1987; 1988; PG&E, 1990; and Honegger, 1998):

> “Natural gas could be considered as the fuel for survival after a major quake. A long period without natural gas for heat, sterilizing water and cooking unrefrigerated food could impair the health of infants, the elderly, the infirm and others particularly during cold winter months.” (SoCalGas, 1987)

But natural gas can also become an agent for disaster! While natural gas performs many useful functions under aseismic conditions, following a major earthquake gas escaping uncontrollably within structures, plus unextinguished pilots acting as ignition sources for spilled flammables and fallen combustibles, can become major factors resulting in roaring infernos that can destroy countless lives and consume hundreds of city blocks. Following a major or great earthquake, or a moderate earthquake during strong winds, a community or city would be far better off without natural gas and electricity for a temporary period of time, while the water system is repaired and a systematic house-by-house effort is made to inspect each one for gas leaks and other fire hazards before gas service is restored. Persons who are especially sensitive to the cold could be taken to temporary shelters until their home and its gas system has been thoroughly inspected, any needed repairs have been made, and the gas service properly and safely restored.

If the electrical system to a city goes down, its gas distribution system is likely to go down, too, within a day or two. Electricity is needed to run the compressors that pressurize the gas, the equipment that pumps the gas into and out of the discovery fields used for storage, and the equipment used to scrub, dessicate, and reodorize the gas. The gas utility may be forced to shut off the distribution system if its odorant pumps are damaged, such as occurred during the Magnitude 6.8, February 28, 2001, Nisqually, Washington, earthquake, when two of Puget Sound Energy’s odorizer pumps shut down; one of which wasn’t repaired until March 6th, a week after the earthquake. After the 1964 Alaska earthquake, the odorant level was doubled to assist in locating damaged piping. Ten days following the February 9, 1971, San Fernando, California, earthquake, SoCalGas shut down the gas-distribution system to approximately 9700 customers in the Sunland-Tujunga area because dirt, rust, and mill scale had shaken loose and clogged control filters at three pressure-regulating valves on an 8-inch distribution line (Hale, 1971; McNorgan, 1973; and Johnson, 1974).

Mandating the installation of SGSVs in earthquake-prone areas is the best way to assure that gas is shut down rapidly and automatically. Relying on gas-company executives and individual homeowners to all quickly make independent decisions to turn off their gas is ill advised. A city with SGSVs on all its structures will help spare gas-company executives the five hours of torment that the board of directors of a large Japanese natural gas company reportedly experienced following the 1995 Kobe earthquake, before it reluctantly decided to shut off the gas supply to their distribution system. But by then it was too late to prevent conflagrations from spawning from the fires they had been watching on TV. If there had been a strong wind at the time, far more than the equivalent of 70 US city blocks would have been burned, and the economic loss would have been far greater than the $200B that has been estimated will be the final figure for that event.

When people use gas to heat their homes, cook food, or boil water following an earthquake, they don’t want to worry that their house might burn down due to gas leaks or other gas-related hazards. Hardships due to the temporary lack of gas following California earthquakes have been minimal. Following the 1933 Long Beach earthquake:

> “…the general public suffered no serious hardships without gas for cooking or heating, although some were uncomfortable. The discomfort was soon alleviated by the combined efforts of every major gas company in southern California in rendering assistance in restoring service. Some four hundred men were soon available for this work, together with a special detail of thirty Los Angeles firemen under the direction of a chief officer, who made a house-to-house inspection before gas was turned on, to assure the occupants of safety as well as to restore confidence in our city. All sections of the city had gas again by March 28.” (Du Ree, 1941)

Rapid shut-off of the gas supply to all structures within strongly shaken areas may decrease the number of persons requiring temporary shelters because less homes will have burned down. Homeless persons are in far greater need of emergency shelter than persons with homes that are temporarily without gas service.

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6.5.1. Fire

The report by Williamson and Groner (2000) restates many of the arguments used by gas utilities to oppose the the mandation of SGSVs (SoCalGas, 1983; 1987; and 1988; and PG&E, 1990). Task Committee Alternate Member Woody Savage of PG&E was the Principal Investigator of the project under whose auspices that report was written and which PG&E helped to fund and oversee. Some statements within the Williamson and Groner (2000) report are insupportable, and, in my opinion, do not make sense from the perspective of improving seismic gas safety.

Most combustion explosions have occurred with less than 25% of the enclosure filled with the flammable gas-air mixture (Kyte, 1986). As explained by former Commissioner J. Marx Ayres:

> "In real buildings with mechanical ventilation heating and cooling, the mixing is very complex due to forces caused by temperature induced air density differentials, location of supply air outlets and return air inlets, location of the gas source and its lighter than air density.
>
> "The gas source can be anywhere in the gas piping system due to leaks caused by movement of the pipe and fittings, a gas pilot light, and pipe failures due to movement of unanchored or restrained appliances. Another concern is the potential of earthquake-induced spillage of flammable liquids and localized combustible mixtures." (Ayres, 2001, Letter to the DSA, October 6, 2001)

There are numerous ways in which a gas-air mixture can be ignited. Ignition of leaking gas can also occur due to the action of turning a light switch on or off, using a telephone, ringing a doorbell, touching a statically charged door knob or other metallic object, frayed wiring, automatic cycling-on of an electrical device such as a lamp or refrigerator, a jammed-on appliance such as an electric can opener, starting a vehicle, activating a garage opener, or the presence of a cigarette smoker. The LAFD warns about using battery-powered flashlights other than the safety/waterproof lights.

If enough fires occur simultaneously, the water system is badly damaged, and strong winds are present, entire neighborhoods and communities could be threatened or consumed by conflagrations, which would jeopardize the safety of many citizens and emergency service personnel.

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6.5.2 Improper Restoration of Gas Service

Lessons learned from the 1933 Long Beach earthquake provide an excellent example to illustrate the potential dangers associated with improper restoration of gas service, and the precautions and education that are needed to help prevent those potential hazards from becoming reality.

It is essential to do a thorough safety check when restoring gas service. Without an internal inspection of the premises by trained and experienced personnel, it is simply impossible to know the condition of the piping, connectors, appliances, flues, and vents, or whether other fire or gas-related hazards are present. It is vital to form and train teams of qualified persons to accomplish this task; and to educate the public about such programs before the next earthquake, as well as in newspapers, fliers, and over the radio, TV, and Internet following the next earthquake.

Following the 1933 Long Beach earthquake, the Long Beach Gas Department ordered all 46,307 gas services in the City to be shut off:

"Two men working together can inspect consumers' appliances, check leakage in house lines, read and turn on approximately sixty meters each ten-hour day, experience of the last two weeks has shown. Crews of twenty-four men under one captain were assigned to each section immediately after the men had passed a test on leakages in mains and service. Each crew was assigned top the various street in each section and as fast as it was possible to do so each house was visited and if found ready for service the meter was read and gas turned on.

" 'In case a leak in the house lines is discovered,' [Long Beach Municipal Gas Superintendent W. H.] Partridge's statement continues, 'the tenant is so notified and the meter is left turned off, a tag warning the consumer not to turn the meter on but to notify the Gas Department when all repairs are completed. Places unoccupied at the time of the survey cannot have the meters turned on as the conditions of the appliances and house piping is, of course, unknown to the workers.'

" 'About 30 per cent of the entire system requires a second or third call before conditions all have been corrected. This means that with 46,000 meters, approximately 14,000 additional calls must be made, or 60,000 calls before the entire city is completed.' " (Long Beach Press Telegram, 1933, "All areas will have gas soon," Long Beach Public Library's collection on the 1933 earthquake)

The prompt shut off the gas supply to the distribution system and individual services is widely credited with having saved Long Beach from a conflagration.

"Estimates have been made of the number of open flames burning at this particular time [5:54 PM], and the figure of 35,000 seems to be within reason—thereby giving us 35,000 potential fires, all starting at one time as stoves were overturned, buildings collapsed, service broken, and so on, with very little thought given by the occupants of the buildings to shutting off the gas before running out." (Du Ree, 1940)

An employee of the Southern Counties Gas Company explained why rapid and automatic shutoff of individual gas services is essential to preventing gas-related fires following earthquakes:

"If the supply to a system which has been ruptured by the 'quake is not shut off, fire and/or explosion, with accompanying hazard to life and property, may result.

"It appears probable that where fire is caused by gas escaping into a building, ignition will in most cases occur immediately, due to pilot lights, open fire, broken wires, etc., within the building, and obviously such fires cannot be avoided by even a prompt decision to shut off the supply following the 'quake." (Bridge, 1934)

And an employee of the Los Angeles Gas and Electric Corporation explained why he believed that mechanical-trip types of SGSVs designed for individual structures, as opposed to SGSVs designed for use in distribution mains, would be the most suitable for earthquake protection:

"…yet it is not satisfactory unless it could be individually designed for each service or supply point, for to have a safety factor that would assure the valve working under all conditions, the damage would be done and the inconvenience of cutting off the gas supply to a multitude of consumers would far offset the probability of the device doing any good in a severe 'quake." (Harris, 1934)

A NIST study on mitigation measures associated with earthquake damage of water heaters notes that:

"the usage of an automatic shut-off valve appears to be theoretically the best way to prevent dangerous gas related fires." (Mroz and Soong, 1997)

7 Options to Reduce Incidence of Fires and Service Disruptions Following Earthquakes

Although there have been many improvements in firefighting capabilities and fire-safety regulations since the 1906 San Francisco earthquake and fire, earthquakes can rapidly degrade those capabilities and compromise the improved safety features. As pointed out by Scawthorn and others (1993), modern cities "contain vastly greater quantities of fuels, hazardous materials, and ignition sources." Post-earthquake fires can quickly overwhelm the fire-fighting capabilities of even our country's largest fire departments. Since the Los Angeles Fire Department (LAFD) was not invited to participate on our Committee, a portion of the testimony provided to the SSC following the 1987 Whittier and 1994 Northridge earthquakes by Fire Chief Frank Borden and Fire Marshal Davis Parsons is repeated below:

> "Earthquake-caused natural gas leaks could cause uncontrolled releases of natural gas from structures, cause and sustain fires, and overwhelm any fire department, including the [LAFD], one of the biggest in the country. On October 1st [1987], the [LAFD] responded to 112 natural gas incidents caused by the Whittier Narrows earthquake. Of those incidents, three were fires. The [LAFD] can respond to only 200 incidents at any one time. He said that the [LAFD]'s position is that controls must be provided to control releases of natural gas from structures and distribution systems to limit the generation of fires. Earthquake-activated automatic gas shutoff valves are a possible solution for structures and distribution systems….Chief Borden said the [LAFD] believes natural gas leaks are a problem after earthquakes, and that the number and size of fires, life and property losses, and the number of responses could be reduced if earthquake-activated automatic gas shutoff valves were installed." (Seismic Safety Commission, 1988)

> "…the most devastating earthquake aftereffects have been due to fire….The bottom line for those who deal with the aftereffects of a major disaster is elimination of the sources of fire. [LAFD Fire Marshal David Parsons] said that was the basis for [the LAFD's] support of seismic valves to be installed in every natural gas installation anywhere a building is erected [in Los Angeles]….He said he believed the city was very fortunate because the Northridge earthquake was not of long duration; the devastation would have been much worse if the shaking had continued a few seconds longer. Also, people were at home, as opposed to being away from home and having problems occur they couldn't attend to. He said many of his employees, before coming to work, ran around their neighborhoods shutting off gas and helping their neighbors, who looked to the firemen to give them a hand. He wondered if there would have been more than the 17,000 leaks that were reported and needed the gas company or the fire department to respond to had the earthquake occurred in the middle of the day when people are away at work. If all those 17,000 leaks had resulted in fires, there most certainly would have been many neighborhoods burning." (Seismic Safety Commission and the Public Utilities Commission's Utilities Safety Branch, 1994)

Market research following the Northridge earthquake showed that many SoCalGas customers are interested in SGSVs:

> "The fact that over 100,000 customers shut off their gas following the Northridge earthquake, even though most had no gas system damage, is in itself an indication of customer interest in seismic valves." (SoCalGas, 1997, "Seismic Services Pilot Program Final Status Report," Letter from Mr. Patrick Petersilia, Director of SoCalGas' Consumer Marketing, to Mr. Paul Clanon, Director of PUC's Energy Division, April 15, 1997)

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7.1 Restraining Appliances Against Earthquake Ground Shaking

Strapping gas appliances alone cannot be expected to eliminate the risk of post-earthquake gas-related fires. To some extent, strapping gas appliances increases the risk of post-earthquake gas-related fires or explosions by increasing the likelihood that pilot lights will stay lit, thereby providing sources of ignition for spilled flammables, fallen combustibles, or gas leaking from deflected threads, cracked elbows, or damaged appliances or connectors thereto. Following strong shaking, a thorough inspection should be made prior to gas system operation or service restoration. Damaged or obstructed vents or flues, or slipped waterheater thermal jackets, can create a CO or asphyxiation hazard. Damaged P&T relief valves on waterheaters can cause explosion hazards.

The fire in San Jose, California, that followed the Magnitude 5.2 earthquake of May 13, 2002, was attributed to the ignition of flammable vapors by the pilot light of a strapped water heater. Following the 1994 Northridge earthquake, SoCalGas found 144 strapped waterheaters that were damaged or leaking (Assembly Committee on Utilities and Commerce, 1994). Strapping waterheaters reduces the risk of gas-related fires, but does not eliminate it.

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7.2.1 Manual Valve

The reason that manually turning off the gas service to a building or facility has been the most common method used in past earthquakes is because manual valves are mandatory, whereas SGSVs designed for installation in residential customer gas piping systems are relatively new inventions and only a few jurisdictions have mandated their installation.

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7.2.2 Seismically Actuated Gas Valves

The State's Standard for SGSVs (12-16-1) requires all customer-owned SGSVs to be installed in accordance with California Plumbing Code. The Internal Association of Plumbing and Mechanical Officials (IAPMO), which is the organization that administers the Uniform Plumbing Code (UPC), has determined that:

> "All components should be considered when sizing/designing gas piping systems. Listed products often meet the flow capacities of the pipe itself. Such items should nonetheless be considered as any device which would limit the required volume of gas, or which would cause an excessive pressure drop would be unacceptable." (UPC Interpretation Committee, 2001, "Interpretation #UPC 01-22," March 19, 2001)

SGSVs should never be installed in parallel lines that merge downstream of those SGSVs. The Los Angeles Building and Safety Department recently modified its approval letters for SGSVs to prohibit such installations.

Most people do not anticipate more than one strong earthquake in a relatively short period. So it is a benefit, not a drawback, that any earthquake—whether a foreshock, mainshock, or aftershock—that is strong enough to exceed the Standard's must-actuate criteria will actuate a properly functioning SGSV regardless of how recently it has been reset. Knowing that the gas service will be shut-off automatically in the event that another strong earthquake should occur provides peace of mind to those who have had their gas service restored. Rapid automatic shutoff with manual reset is the only way to assure that the necessary time is available to check or re-check a structure for gas-related fire hazards.

The risk of structural damage rendering a SGSV ineffective could be mitigated by having the gas utility relocate its meter set to a less vulnerable location (such as into a below-grade vault with a steel-plate cover) and installing the SGSV into a separate vault just downstream of the gas utility's vault. Except for a few rare situations pertaining to commercial or industrial structures, all utility-owned pressure regulators and meters should be moved outside of buildings, so that the SGSV can be installed downstream of the meter and upstream of the piping system's first entry into or under the building.

The current national and State Standards for SGSVs do not require SGSVs to have good flow characteristics relative to their nominal size (i.e., the size of their threaded or flanged ends). As a predictable result, some

SGSVs have poor flow characteristics. All proposed installations of any gas valve with poor flow characteristics should be subjected to review through a procedure called mechanical plancheck, which in California is performed by a registered mechanical engineer, and is subject to review and approval by the authority having jurisdiction. The Southern California Chapter of IAPMO pointed out, in regard to a postulated attempt to plancheck the installation of a 3/4" gas valve with a severe pressure loss:

> "This would greatly increase the pipe size of the system and increase the potential for leaks and breakage." (Letter dated June 1, 1987, from Mr. Ed Saltzberg, on behalf of the Southern California Chapter of IAPMO, to the Office of the State Architect)

Los Angeles County pointed out that the insistence on using a gas valve that creates severe pressure losses can:

> "...require the owner of the structure to incur the cost of preparing plans and calculations and the possibility of costly repairs to the existing gas piping system." (Department of Public Works of the County of Los Angeles, 1998, Letter to Mr. Les Saffil, May 26, 1998)

Los Angeles County waives mechanical planchecks for installations of SGSVs whose equivalent length (in terms of the internal friction loss of straight schedule-40 pipe of the same nominal size) is no more than 10'. Because Los Angeles County's plancheck waivers for SGSVs with good flow characteristics relative to the systems that they are proposed to be installed in are based on sound engineering principles (i.e., the shortest interval in the UPC's pipe-sizing table for low-pressure gas piping systems is 10'), this approach makes sense for use in all California jurisdictions, since all California jurisdictions use the UPC. Installation of a gas valve with poor flow characteristics can lead to line starvation under full demand, which can lead to inefficient operation of appliances at best, or potentially deadly explosions at worst.

It is common sense that every gas-serviced building should be included within the scope of a SGSV mandate, because in the aftermath of an earthquake all gas-serviced buildings are at risk from gas-related fires originating from within and without. The argument that restoration of gas-service by unqualified persons could lead to increased risk is illogical. Most persons are deathly afraid of having anything to do with their home's gas system, and will gladly wait until the gas company or a licensed plumber is available to check their system for potential damage. The greater risk lies in repercussions that can occur from not rapidly shutting off the gas whenever strong ground shaking occurs. The same persons whom gas utilities claim are unqualified to restore their gas service following an earthquake are equally unqualified to determine whether to shut it off. Rapid and automatic shutoff of the gas supply to individual structures buys the necessary time to thoroughly check for potential hazards before gas service is restored.

The well-defined seismic response specifications in the present national and State Standards for SGSVs include a margin of conservatism, which makes these devices well-suited for widespread use throughout California and for a wide variety of building types. The occurrence of automatic gas shut-off during strong ground motion in the absence of damage to the gas piping system, gas connectors, gas appliances, or the presence of other earthquake-related gas hazards, is expected to be so rare that most gas customers are willing to accept that rare inconvenience in exchange for the peace of mind that their gas service will be rapidly and automatically shut off in the event of an earthquake large enough to pose a risk of fire or explosion. Earthquake safety information advises citizens to store at least 3 days of food and water for emergency purposes.

Widespread installation of SGSVs may greatly reduce the number of unnecessary shut-offs that typically occur following moderate or larger earthquakes; and may also reduce the number of 9-1-1 calls to overtaxed fire departments to request investigation of gas odors due to extinguished pilots, which would free up fire-service personnel and apparatus to fight fires and rescue people.

SGSVs should not be viewed as a means of reducing the potential for gas-related fires only in buildings that are unlikely to suffer significant structural damage, because it is more likely for persons to become trapped in such buildings, rendering them helpless in the event of gas leaks or fire. It is illogical for owners of buildings that are more prone to suffering structural damage during earthquakes to discount the risk of gas-related fires; nor is that a sound practice for communities.

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7.3 Excess Flow Valves

No studies have been done to show that low-pressure excess flow valves (LPEFVs) might be beneficial in the event of an earthquake. In addition, there are several safety issues concerning the use of LPEFVs in typical low-pressure gas piping systems. This is because the State adopted a nonconsensus standard, and has treated that standard in a nonconsensus manner.

In the year 2000, fellow Committee Member Jim McGill and I submitted written objections to the Division of the State Architect (DSA) regarding its intention to adopt a nonconsensus standard—CSA U.S. Requirements 3-92—as the State's Standard for LPEFVs. The DSA asked the Building Standards Commission (BSC) for an extension so that it could hold a hearing to discuss the objections we had raised; however, the BSC rejected the DSA's request for such an extension; and the DSA then acted on November 15, 2000, to adopt the aforementioned nonconsensus standard. The DSA referred to the nonconsensus standard for LPEFVs several times during the course of the adoption procedure as a "nationally recognized standard" and a "model standard"—terms that the federal government does not apply to nonconsensus standards. The federal government requires voluntary consensus standards to have openness, balance of interest, due process, an appeals process, and consensus (Executive Office of the President, 1998), none of which apply to CSA US Requirements 3-92.

In response to the DSA's invitation, Mr. McGill and I submitted several specific suggested revisions and supporting reasons to the DSA for its consideration. The DSA conducted a public meeting on December 12, 2000, to discuss our suggested revisions. On or before January 3, 2001, the DSA submitted paraphrased versions of those suggested revisions and supporting reasons to the BSC as recommended amendments for consideration by the BSC during the State's annual code-review cycle (DSA, 2001). The DSA informed Mr. McGill and me that its recommended amendments had been assigned to the BSC's Plumbing, Electrical, Mechanical, & Energy (PEME) Code Advisory Committee for consideration during its annual meeting on March 5 and 6, 2001.

However, on February 8, 2001, the State Architect wrote the BSC to withdraw the recommended amendments, primarily on the basis that the issues concerning those recommendations would be considered by a Task Committee being formed by the Seismic Safety Commission; and on February 15, 2001, the DSA sent letters to that effect to Mr. McGill and me. Of course, this is the same Task Committee that has failed to consider the technical merits of EFVs.

On March 27 and October 17, 2001, the DSA held meetings at its headquarters to discuss the ramifications of its withdrawal of its recommended amendments to State Standard 12-16-2; but has yet to take appropriate action. I summarized the discussions that took place during those meetings in letters to the DSA dated May 3, 2001, and February 15, 2002, respectively.

As a result of all of the above, the State is currently saddled with a Standard for LPEFVs that has never been subjected to the public scrutiny and revision that is the hallmark of consensus standards. And this is why the DSA is now certifying LPEFVs that have one or more of the following potential safety problems:

1) LPEFVs have internal pressure losses so large that their use can cause the pressure loss for a typical low-pressure gas-piping system to exceed the UPC's pressure-loss allowance. Basic engineering textbooks warn against installing restrictions inside gas piping:

> *"No device shall be placed inside the gas piping or fittings that will reduce the cross-sectional area or otherwise obstruct the free flow of gas."* (Segeler, 1967)

2) LPEFVs have inaccurate closing flow rates, C_v values, & equivalent lengths. State Standard 12-16-2 allows a LPEFV's actual closing flow rate to be 80% to 110% of its labeled closing flow rate; and does not address the effects on the actual closing flow rate for LPEFVs that are installed in lines containing vaporous propane, which is 250% denser than natural gas.

3) LPEFVs don't actuate in response to the vast majority of gas leaks deemed "significant" under the federal government's guidelines for gas safety. The federal gas-safety program is built around the concept that any gas leak of unknown origin inside a building that is strong enough to be smelled by a healthy person with a normal sense of smell should be considered potentially dangerous. Federal regulations require fuel gases to be odorized so that they can be smelled by a person with a normal sense of smell at 1/5 of the lower explosive limit (LEL), which means a gas-air mixture of about 1% for natural gas (whose LEL is about 4.6%) and about 0.5% for vaporous propane (whose LEL is about 2.4%).

4) Most LPEFVs never shut off, even in their actuated positions, but rather have "bypass flows" or "bleed-by flows," which are the terms that LPEFV manufacturers and distributors choose to use instead of the term "internal leakage." State Standard 12-16-2 allows up to 10 CFH (the rate of gas flow consumed by a typical range burner) to pass through LPEFVs in their actuated position.

5) Automatic reset type LPEFVs, which are by far the most common type on the market, can automatically reset without the performance of a witnessed air pressure test to 10 psig for 15 minutes (as required by UPC Sections 1206 and 1207), a meter-clock test by the gas utility (as required by the CPUC, according to a statement made by fellow Committee Member Raffy Stepanian during our Committee's first meeting), or purging of the system. Purging should always be done before restoring service to a gas system that has suffered damage:

> *"After piping has been checked, all piping receiving gas shall be fully purged. A suggested method for purging the gas piping to an appliance is to disconnect the pilot piping at the outlet of the pilot valve. Under no circumstances shall piping be purged into the combustion chamber of an appliance. After the gas piping has been sufficiently purged, all appliances shall be purged and the pilots lighted. The installing agency shall assure that all piping and appliances are fully purged before leaving the premises."* (Segeler, 1967)

6 Line-size reductions (which are common in conventional low-pressure gas piping systems) downstream of an LPEFV can render that LPEFV incapable of actuating even if there is a complete break in the line downstream of the size reduction (NIOSH, 1998; and Staff of the Factory Mutual Engineering Division, 1959).

The federal government noted the following concerns in response to its proposal that pipeline EFVs must close whenever "the service line is severed or if the customer's meter, regulator, or service valve is sheared off":

> "Most commenters cannot guarantee that an EFV will perform as designed and warranted by the manufacturer. One commenter said that it would be difficult to comply with such a requirement because EFVs often fail to activate (due to fluid friction) in longer service line lengths of ½-inch pipe. Also, even if the meter is sheared off, the flow rate may not exceed the EFV activation flow rate because the pipe may be squeezed off at the point where it is sheared, or because there are other restrictions in the line." (DOT, 1996)

7 LPEFVs are not required to have a means of determining whether they are open or closed.

8 LPEFVs are subject to being fouled by contaminants commonly found in gas services, including rust, dust, and mill-scale deposits:

> *"Gas distribution companies have had much experience and difficulty with foreign matter (particulants) in gas mains and services. These rust, dust and mill scale deposits cause fouling of some equipment and since any excess flow device must necessarily restrict flow in order to function, they are subject to*

malfunction due to foreign matter being carried along in the gas stream. In the opinion of the writer, all of the excess flow valves listed above are subject to malfunction due to accumulations of rust, dust or mill scale." (Platus, MacKenzie, and Morse, 1974)

LPEFVs containing internal magnets are probably more susceptible to this problem than those that don't.

9 An LPEFV can actuate under everyday conditions if its closing flow rate is less than the full demand of the system downstream of it. This can cause the extinguishing of pilot lights and the flow of unignited gas into a building:

"Those who publicly oppose the concept of excess flow valves often state that under some conditions, the devices may pose a greater hazard than the problem they are intended to prevent. To determine how widespread this concern was among the companies interviewed and to obtain more specific information, the companies were asked if there exist 'any instances or circumstances where a risk to public safety could be introduced by installing excess flow valves.' Only seven companies responding to this hypothetical question could foresee no such circumstances. A majority of the conceived hazards involved the bleed-by flow of gas from a 'closed' excess flow valve. Eighteen companies offered as an example the possible case where a false closure of an excess flow valve extinguishes the pilots on appliances within a building, resulting in the flow of unignited gas into the building. Variations on this basic theme included the excess flow valve automatically resetting to its open position, appliances with no safety pilot valves or malfunctioning safety valves, and range burners open at the time of the false closure….Five companies stated that the bleed-by flow, while considerably less than the delivery capacity of the pipe, could be hazardously large…..Five companies stated that their system pressures were too low or too variable….Four companies stated that most leaks, and especially those involving severe consequences, are small and would not activate an excess flow valve." (NTSB, 1981, pp. 29-30)

Certain LPEFV manufacturers and several other parties have likened the function of EFVs to that of electrical fuses or circuit breakers (Gas Utility and Pipeline Industries, Inc., 2000; and NTSB, 1980); however, EFVs of all types function quite differently than fuses or circuit breakers.

In 1987, the DSA's predecessor, the Office of the State Architect (OSA), reacted in less than 2 weeks when presented with information about the high pressure losses created across a certain brand of SGSV. The OSA appealed to the manufacturer to "…limit the scope of [its] sales and provide warnings and directions to [its] customers as appropriate." The OSA told the manufacturer that "Review of previously installed units and retroactive measures should also be considered as a high priority." The OSA's letter also stated:

"Our quick appraisal suggests (as per notes added) that the ¾" valve capacity is effectively equivalent to that of a ½" valve with a high pressure loss. This condition could contribute to a malfunction or starvation of remote appliances. The same condition is predictably relevant to the 2" size also.

"Please be prepared to provide public warnings relative to limitations in the safe use of the Quakemaster valve system and after we have reviewed your comments, please submit your proposals for product changes, warnings, new tests, etc. as soon as possible." (OSA, 1987, Letter to Quakemaster, Inc., June 12, 1987)

But when presented with similar information about the high pressure losses created across LPEFVs, the DSA has failed to write similar letters to the manufacturers of such devices.

Senate Bill SB 384, which was introduced less than two weeks after the State Architect withdrew the DSA's recommended amendments to State Standard 12-16-2, sought to mandate the installation of LPEFVs throughout the State. It is apparent from the wording of SB 384 that the LPEFV lobby informed its author about the NTSB's support of the DOT's customer-notification requirement for the installation of high-pressure EFVs in new or exposed outdoor service lines that supply gas to single-family residences and are operated at a minimum pressure of 10 psig year round. It is equally apparent that they did not inform him about the NTSB's warnings against using EFVs in low-pressure lines:

> *"Most of the excess flow valves described in this section are intended for use only in high-pressure services. In high-pressure services, above several psig, the pressure loss across an excess flow valve is of little consequence. However, some manufacturers and gas companies have stated to the Safety Board that this pressure loss is of critical importance in services operating at utilization pressures, typically ¼ psig."* (NTSB, 1981, p. 2)

I believe the State should issue appropriate warnings to the public concerning the potential safety hazards that can be created by the installation of low-pressure EFVs. I believe the State should also issue, or require the issuance of, disconnect notices for all customer natural-gas or vaporous-propane services in the State in which one or more LPEFVs has been installed without mechanical plancheck, with such disconnect notices to remain in effect until such time as those devices have been removed or a mechanical plancheck has been performed by a registered mechanical engineer and the plancheck's recommendations satisfied.

Ayres (2002) shows that installation in a conventional low-pressure gas piping system of one or more of any of the EFVs that have been submitted to the Division of the State Architect (DSA) for consideration of the State's certification would cause such a system to become noncompliant with the Uniform Plumbing Code's maximum pressure-loss allowance.

Fellow Committee Member Paul Brooks remarked during our 3rd meeting that he thought LPEFVs were better than nothing. However, as determined by the report by former Commissioner J. Marx Ayres (Ayres, 2002), installing LPEFVs can actually be worse than doing nothing, because their use in conventional low-pressure gas piping systems without mechanical plan check will almost invariably violate the UPC's pressure-loss allowance, which can cause line starvation under everyday conditions.

Because our Committee's leadership prevented us from fulfilling the promise made by the State Architect to the BSC on February 8, 2001, that this Task Committee would address technical and safety concerns raised in regard to the use of LPEFVs, it is inappropriate for our Committee to recommend or encourage citizens to install such products.

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Table 9

Installing one or more of any of the EFVs that were submitted to the DSA prior to November 2, 2001, and perhaps all that have been submitted since, for consideration of the State's certification would generally cause a violation of the Uniform Plumbing Code's pressure-loss allowance (Ayres, J. Marx, 2002, "Low pressure excess flow natural gas valves, Uniform Plumbing Code application requirements"). The SSC should be warning citizens about the potential hazards of installing such devices in typical low-pressure gas piping systems, instead of encouraging citizens to install such devices by showing the locations where their manufacturers are promoting their installation.

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8.0 Community Preparedness and Response Planning

While emphasizing that the disruption of gas service may result in costs associated with emergency services and loss of revenue due to interruption of business service, the majority report fails to mention the potentially devastating costs in terms of human lives and property of failing to rapidly disrupt the gas service in heavily shaken areas immediately following a strong earthquake.

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Table 8 Comparison of Alternatives to Improve Gas Safety in Earthquakes

"Excess Flow Valves" should not have been included in this table, because no study has been done to show that installing EFVs would improve gas safety in earthquakes; and also because an engineering study has shown that the LPEFVs submitted in the year 2001 to the DSA for consideration of the State's certification cannot be installed in conventional low-pressure gas piping systems without violating the UPC (except perhaps in the rarest of circumstances and only at considerable expense and inconvenience).

The column headed "Reduce chance of unnecessary gas shutoff" should not have been included in this table, because it is merely the opinion of PG&E and is highly debatable. For locations where the strong ground shaking is less than necessary to actuate an installed SGSV, there would be a reduced chance of unnecessary gas shut-off. At such locations with well-built single-family homes, many persons would choose not to manually turn off their gas, because they would know that the installed SGSV is designed to automatically shut off their gas for them if the shaking exceeds a certain threshold below which it is unlikely that their home's gas system will have a gas leak. On the other hand, installed LPEFVs can actually increase the number of unnecessary shut-offs, because people would have no idea whether their LPEFVs were open or closed, and because LPEFVs do not provide any protection from most significant gas leaks.

This table downplays the value of installing SGSVs and discourages jurisdictions from mandating them. For over a decade, PG&E has used the argument that widespread use of SGSVs would cause unnecessary shutoffs to support its strong opposition to efforts to mandate their installation. Having a SGSV can actually decrease the likelihood of unnecessary gas shut-offs, rather than increase the likelihood, if homeowners are educated that these types of devices are designed to actuate prior to strong ground shaking of an intensity likely to cause a gas leak in their home's gas piping system.

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Section 9 Cost and Benefit Considerations

This section misuses statistics to support the opposition of the sponsoring gas utilities (especially PG&E) to mandating SGSVs. It makes reported occurrences seem like risks; yet many of the earthquakes in the database were moderate in size and were accompanied by fortuitous circumstances. Californians have been lucky to date, and the risks are much greater than the reported occurrences. Larger earthquakes can occur; also, it would be foolish to rely on fortuitous circumstances occurring during future earthquakes. The largest earthquake in the database, the M 9.2 Alaska earthquake of 1964, was not accompanied by any gas-related structural fires because the strongly shaken area was sparsely populated, and the natural gas distribution system in Anchorage was broken in numerous locations by landslides and ground settlement.

The number of natural gas leaks that were recorded following the 1971 San Fernando earthquake was nearly 15 times the daily average (Aroni, 1987). Because many gas leaks caused by earthquakes are not reported, and many of those that are reported are not recorded due to the heavy workload of emergency services staff, the rate of occurrence of gas leaks must have been far greater than under aseismic conditions.

It was inappropriate for our Committee's Consultant to have ignored the exhortations of several Committee Members to request Dr. Charles Scawthorn, who was instrumental in developing the HAZUS methodology, to review this section.

In Table 10, the rows that are headed "Excess Flow Valve at Meter" and "Excess Flow Valve at Appliance" should not have been be included, because LPEFVs are not fit for use in conventional low-pressure gas piping systems due to their high pressure losses (see Ayres, 2002), and also because no study has been done to show that the use of such devices would significantly reduce the risk of gas-related fires after earthquakes.

Relating the benefit to an individual gas customer of installing a SGSV to their perception of the risk from post-earthquake natural gas ignitions intentionally downplays the actual risk to individual households as well as to communities.

Each and every fire ignition during or in the aftermath of an earthquake threatens not only the individual and his family, and their own home, but also, if the earthquake is strong enough, all the persons and buildings in their community or city. The fact that different individuals have different risk tolerances has no bearing whatsoever on the best interests of the community or city when it comes to minimizing the risk of conflagration following earthquake.

It is a waste of time to do these kinds of calculations on a case-by-case basis for individual structures, using data from only a few moderate-sized earthquakes that were accompanied by fortuitous circumstances. The only value that these kinds of calculations have is their snooker value by those who wish to persuade people into thinking that mandating the installation of SGSVs is unnecessary or too expensive. At an average total cost of, say, $300 per proper installation on a typical single-family residence—assuming a SGSV model is chosen whose flow characteristics are appropriate for the building's properly sized gas piping stub—it is easy to see that these kinds of costs born by individual homeowners and businesses are extremely reasonable compared to the risk of a windswept conflagration in a major California city, which could cause the loss of over 100,000 lives and upwards of one trillion dollars in economic loss; not to mention the lingering effects for many years and even decades on the regional, California, US, and global economies. We should not lose sight of the big picture!

It is miraculous that the fires we have experienced in California following earthquakes since the 1906 San Francisco calamity have not been far worse.

When it comes considering whether to implement the mandation of seismic gas safety devices, the role of fire insurance is currently relatively small. Insurers and reinsurers could play a bigger role by offering lower premiums in those areas where mandates have been issued and are being implemented and enforced.

The main problem with trying to use HAZUS data to model post-earthquake fire ignitions is that buildings are not always occupied by responsible and capable persons. For most of the earthquakes in the HAZUS database, a large percentage of people were home to shut off their gas or electricity, put out fires, and call for assistance; also, winds were light.

Many persons, companies, schools, and government agencies within California—and elsewhere—have elected to have SGSVs installed on their customer gas lines on a discretionary basis, which is evidence that many find the associated costs reasonable. Furthermore, Los Angeles' mandate for installing SGSVs has proven that costs do come down with volume and competition, and that nuisance tripping is not a significant problem.

Because the costs to install SGSVs that are mandated are borne in most part by homeowners and businesses, the costs incurred by governments issuing such mandates are largely limited to installing them on the buildings that they own or operate, plus perhaps the buildings that are pre-designated as emergency shelters (to help assure that those buildings will survive to perform their intended function). There are many benefits associated with installing SGSVs on public buildings in terms of their function, occupancies, and contents.

There are also costs associated with enforcement of the mandation, some of which could be recouped through permit and plancheck fees or noncompliance penalties. Some governments may choose to assist low-income persons to install SGSVs, because low-income persons are more likely to live in buildings that are not up to current building codes or are located in areas that are more susceptible to strong ground amplification or liquefaction. Areas with a high percentage of older building stock and poor soil conditions are important to protect, because fires spawned there can spread to parts of the community or city with newer building stock or better soil conditions.

Figure 6 and much of the accompanying text should not have been included in the report. Those arguments are based on data collected primarily from moderate-sized earthquakes that happened to be accompanied by fortuitous circumstances, and are therefore an invalid statistical basis. It is fortunate that winds were light during the 1971 San Fernando, 1987 Whittier Narrows, 1989 Loma Prieta, and 1994 Northridge earthquakes; gas was shut off promptly to the distribution systems feeding the heavily damaged areas following the 1925 Santa Barbara and 1933 Long Beach earthquakes; gas was shut off promptly at all individual structures in the heavily damaged area following the 1933 Long Beach earthquake; no children or teachers were trapped in the 7 schools that caught on fire following the 1933 Long Beach earthquake; the Anchorage gas distribution system was broken up by landslides and settlement during the 1964 Alaska earthquake, and all 4 major gas mains feeding the heavily damaged area were sheared by surface-fault rupture during the 1971 San Fernando earthquake. The list of lucky coincidences goes on—but cannot continue forever!

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9.1 Individual Perspective

This section falsely assumes that the actual risk during future earthquakes is the same as the rate of occurrence during a few moderate-sized earthquakes that were accompanied by fortuitous circumstances. It downplays the risk by shifting attention away from serious discussions about mandating SGSVs to a myriad of other issues. Instead of talking about risk in a realistic manner, it talks about the perception of risk and how much disposable income individuals might have as the factors that might trigger such individuals to have a SGSV installed on their building's gas line.

It is impossible to reliably predict how often a person will be at home and capable of manually turning off their gas in time to prevent a gas-related fire, or how often a neighbor will be at home to turn off their gas for them—and presumably their own and all their other absent neighbors' gas services as well. Not many persons will venture into their neighbors' homes to smell for gas leaks and turn off gas services following earthquakes; and besides, they are bound to have their hands full with urgent problems of their own.

A single-family dwelling occupied by two adults and their two children during the M 7.3 Landers earthquake of June 28, 1992, was a total loss due to a gas fire; so just because responsible persons are at home is no assurance that they will manually turn off their gas service in time to prevent a gas-related fire.

This section mistakenly equates the rate of occurrence as the "probability of an earthquake fire ignition." It also mistakenly attributes being trapped in a building as the only life-safety risk associated with fire following earthquake. Flying brands at a time with no piped water, impaired communications, and overwhelmed fire departments can quickly jeopardize the lives and property of entire communities.

The tendency for lesser valued homes to be concentrated in areas of higher seismic risk supports the argument for mandating SGSVs, because fires spawned in one part of a city can spread to other parts, thereby also jeopardizing the lives and property of those in affluent areas where better-built homes tend to be concentrated. It is important to help finance the installation of SGSVs in less-privileged neighborhoods.

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9.2 Community Perspective

This section shifts attention away from a serious discussion of the many benefits that can be derived from mandating the installation of SGSVs. It is ridiculous to talk about lost investment opportunity and recovery of costs through insurance. Following a conflagration, some insurance companies can be expected to become insolvent, just as many did following the 1906 San Francisco earthquake.

Gas-safety experts recommend shutting off the gas whenever a gas leak is detected or suspected inside a building. Therefore, our report should not be recommending the use of any products that only limit the flow of gas.

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10.0 Conclusions and Recommendations

Jurisdictions considering whether to mandate the installation of SGSVs should not abandon that strategy in favor of letting each individual building owner decide what to do on a case-by-case basis. Attributing a person's desire to install a SGSV merely on their level of affluence downplays the safety added by a proper installation, and emphasizes the need to mandate the installation of such devices. By shifting the focus away from actual risk to perceived risk, the affluence of individuals, and case-by-case evaluations, the majority report is embracing the arguments expressed in the gas utilities' position papers.

If a conflagration were to occur, then more buildings could be damaged and lives lost from fire than from the shaking.

Gas-restoration efforts are not entirely a result of individual gas services being shut off. Damage to gas distribution systems and equipment, loss of electricity, and damage to the water-distribution system can also result in widespread and prolonged gas outages.

It is inappropriate for our report to conclude that using LPEFVs is cost effective, because no study has been done to show that the use of such devices would be effective in reducing the number of post-earthquake fires.

The DSA should not continue its certification program for LPEFVs. Instead, the DSA should repeal its Standard 12-16-2 for LPEFVs, and issue warnings to current and potential users of such devices about the potential hazards of using LPEFVs in typical low-pressure gas piping systems.

The State Fire Marshal should not inform jurisdictions that the potential loss of life from fire following earthquakes is largely limited to older multi-unit residential buildings (not that such risk isn't significant).

The DSA should be given enforcement power to assure that non-certified devices that are required to be certified are not sold in this State.

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Insert for Homeowners' Guide

Aftershocks are earthquakes that occur following a mainshock. Any earthquake strong enough to actuate a properly installed SGSV is strong enough to justify shutting off the gas. For decades, PG&E and SoCalGas have used the fact that aftershocks can cause SGSVs to actuate after the gas service has been restored to support their arguments against mandating SGSVs. But strong aftershocks can cause numerous simultaneous gas leaks, which can lead to fires or explosions, and at a time when the emergency services are likely to be overwhelmed from dealing with the effects of the mainshock; and damaged water, transportation, and communication systems have yet to be repaired. It is beneficial that strong aftershocks can actuate SGSVs after they have been reset.

The comment about limited loss of life in single-family houses is inappropriate. The following hazards should have been listed: fire, explosion, spilled flammables, fallen combustibles, damaged vents and flues, asphyxiation, & CO poisoning. Strong shaking can also cause fires by spilling flammables or knocking over combustibles stored near gas appliances, so be sure that no flammables or combustibles are stored near gas appliances. Besides being a fire hazard, leaking gas can also cause death by asphyxiation. Operating a gas system with damaged vents or flues can cause death or permanent nerve damage from carbon monoxide poisoning.

Do not activate or use any electrical appliances or switches, or make any phone calls from inside the house. If your gas service has been shut off, whether manually or automatically, do not attempt to restore service until a qualified professional has checked your system for safety.

The column headed "Excess Flow Valves" should have been omitted, since such devices cannot be installed in typical low-pressure gas piping systems without causing a violation of the Uniform Plumbing Code (see Ayres, 2002); and also because most of the devices on the market can automatically reset.

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