Hydrogen Production:
A by-product of living in a golf cart community

Leading Community Risk Reduction

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Abstract

During the summer of 2003 the Villages Public Safety Department (VPSD) responded to a number of carbon monoxide activations in private residences. In several of the incidents it became apparent that nothing in the home was capable of generating carbon monoxide (CO). However, the culprit for the activations was attributed to golf cart being overcharged in the golf carts. The golf carts were found to be off-gassing hydrogen, and causing a false positive for the CO detectors. Because of the significant number of golf carts in the community this was deemed to be a significant risk to the community.

The problem is that the VPSD and the Village Center Community Development District (VCCDD) do not have a risk reduction program in place to efficiently and effectively mitigate the potentially deadly effects of hydrogen off-gassing from an overcharged golf cart battery. The purpose of this research project is to identify the dangers of golf cart batteries being overcharged in private residences in The Villages and to implement a formal risk reduction program to reduce and eliminate the dangers to the community and emergency response personnel.

This study will employ action methodology supported by historical and descriptive methods. The following questions will be used in performing the necessary research and compilation of data:

1. What is the impact of over-charged golf cart batteries to the community?
2. Has another emergency response agency or community experienced a similar situations involving overcharged golf cart batteries?
3. What needs to be done to mitigate this situation?
4. What emergency response procedures exist, or should be implemented, in the event of a hydrogen release?

The research involved two surveys. The first survey conducted involved Villages residents to determine the specific number of hydrogen producing sources in the community. The survey was distributed to 185 residents with 159 surveys returned. The second survey was distributed to eleven

emergency services providers responsible for protecting “golf cart” communities. This survey was conducted via phone. This was done to expedite survey returns and achieve a 100% return rate.

Interviews were conducted with CO detector and battery manufacturers. Each of the interviews was conducted via phone using a standard list of interview questions to insure a base line of information was received. Service technicians and scientists from the CO detector manufacturers provided answers pertaining to the effects of hydrogen on CO detectors. Environmental scientists from the battery manufacturers provided answers pertaining to the quantities of hydrogen being produced by overcharged batteries.

The resident survey indicated that 96,23% of respondents owned a golf cart and 83.12% of respondents owned electric golf carts. The emergency services provider survey reveled that only one agency was aware of the fact that hydrogen caused the false positive reading in CO detectors. However, none of the agencies had addressed the situation through a risk reduction program. The manufacturer survey indicated that CO detectors would alarm when hydrogen gas was present in amounts of 300 ppm.

The recommendations made from this project focused on increasing public awareness by utilizing the local television and newspaper media. In addition, the department would create a public education brochure to be distributed at special events. The department would also work with the Villages Homeowners Association to add this information to their current golf cart driving safety program.

Table of contents

Introduction

The production of hydrogen is typically thought of as being an intentional and formal process. Hydrogen is used in large amounts by NASA as an efficient fuel to propel the space shuttles and other rockets into orbit. Hydrogen is also being investigated as an alternative fuel for the automobile industry as it tries to modify the internal combustion engine because of environmental concerns. In these controlled environs hydrogen is a very safe product and very few accidents have been recorded.

Hydrogen gained notoriety because of the *Hindenburg* explosion. This accident demonstrated the disastrous effects of an uncontrolled hydrogen release. Outside of a controlled environment hydrogen can have devastating effects on the community and its residents.

The risks identified by this research project came to the attention of the Villages Public Safety Department (VPSD) because of a significant number of carbon monoxide (CO) detector activations in private residences. As the department began to investigate these incidents a commonality began to appear. Time and again the source of the activation was believed to be an over-charged golf cart battery. This produced a degree of confusion in the department since lead acid golf cart batteries produce no carbon monoxide in the chemical reaction that creates electricity. Continued investigation and work with battery and CO detector manufacturers identified the fact that hydrogen is capable of causing a “false-positive” in the CO detector.

Even though the detectors were activating when no CO was present, the detectors have been credited with saving the lives of several homeowners. In this incident the homeowners had left their golf cart on charge while away from home. They returned home to find the CO detector in alarm and they chose to ignore the alarm because they felt the detector was at fault. Approximately two hours after their return home they called 911 complaining of headache and nausea.

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Background and Significance

The Villages is a retirement community located in the heart of Central Florida. The growth of the community is governed by The Village Center Community Development District (VCCDD). The VCCDD is a unit of "special purpose" local government established by Florida State Statue to oversee the growth of The Villages and provide municipal services to an unincorporated part of Sumter County (Florida State Statute 190). These responsibilities include fire protection, fire prevention, and emergency medical services through the Villages Public Safety Department (VPSD) (Sumter County Interlocal Agreement).

The VPSD currently staffs three stations with 30 emergency response personnel. A proactive growth plan allows for additional emergency response personnel for every 2,250 homes constructed (VPSD Strategic Plan, 2002). This plan insures that the emergency services provider can keep pace with the community it is charged to protect.

The community presents a lifestyle strongly centered around golf and recreation. As a result, the golf cart is viewed as an essential by many residents and has become the second family car. In some cases it is the only form of transportation. In addition to golf carts, low speed vehicles (LSV) are also becoming common sights. The current population of the community is approximately 44,000 residents with an average per home population of approximately 1.9 persons (Lester, G., personal interview, September 28, 2003). This equates to approximately 23,000 residential units with 96.23% having golf carts in them. Statistically this translates to a potential of 22,285 golf carts in private residences. In addition, 83.12% of survey respondents indicate they own electric golf carts (Appendix "A"). This translates to a potential of 18,523 electric golf carts in the community. The projected "build out" population of the community is 104,000 residents (VPSD strategic plan, 2002). With this continued growth the community could potential have 45,498 electric golf carts.

Through anecdotal information and incident reporting data the department began to notice an increase in CO detector activations. In some instances a source of CO could not be identified and was ultimately assumed to be golf carts being left to charge for extended periods of time. The identification of the source was supported by VPSD CO gas detectors. As the department began to research the causes of these alarms, it became apparent that lead acid batteries do not emit CO, but actually emit hydrogen. Due to the extremely explosive and flammable characteristics (Voltaix, 1994) of hydrogen, the number of golf carts in the community was indicative of a potentially severe problem.

In some instances it became apparent to VPSD personnel that many of the overcharged golf carts did not have a battery charger specifically designed for use with the golf cart involved. The department conduct a survey and 5.19% of the respondents indicated that they had purchased a battery charger specifically design for you use with their golf cart. In addition, only 4.55% of the respondents indicated they still owned the battery charger that had come with the golf cart. The survey also identified the fact that 35.71% of the respondents also keep their golf carts charging at all times (Appendix "A").

The author believed this project fit into the design and intent of the Leading Community Risk Reduction course due to the potentially significant impact upon the community. In addition this project will work to advance the five-year plan of the U.S. Fire Administration's goal of reducing the loss of life from fire by 15%. The project will also support the goal of the LCRR course by designing and implementing a comprehensive risk reduction program for The Villages (National Fire Academy, 2003).

Literature Review

The literature review was performed using the Lake County Public Library System, the Sumter County Public Library System, the Lake-Sumter Community College Library, the University of Central Florida Library, and the National Fire Academy's Learning Resource Center. Additionally, the Internet also provided valuable sources of information. Initial search efforts focused on the terms "golf cart batteries," "over-charged golf carts," "hydrogen gas accidents," "battery explosions hydrogen levels," and "golf cart communities". These search terms identified several sources of information outside of the fire and emergency services that proved to be relevant to the issue.

According to an article produced by Calicorp, Inc. batteries produce hydrogen gas even under normal operation (Calicorp, 1999). The article reviews the number of lead acid batteries in use in the United States and discusses the many non-vehicular uses of these batteries.

NIOSH addressed the subject of hydrogen build-up and explosions in the fire service after two firefighters involved in separate incidents were slightly injured when the flashlights they were using exploded (NIOSH, 2000). This article reviews the reasons why the batteries exploded: improper use of rechargeable and non-rechargeable batteries. The improper use of the batteries resulted in excessive hydrogen being created.

The United States Coast Guard released a Marine Safety Center Technical Note identifying the dangers of hydrogen gas build-up in the battery compartment of a submersible vehicle. This document outlined the specific conditions that must exist to cause an explosive situation. The correlating characteristics between the battery and passenger compartments of a submersible vehicle are strikingly similar to those of the household garage and living area typical to The Villages residential units (United States Coast Guard, 1996). Safety literature produced by the Data Buoy Cooperation Panel (DBCP) reviewed information pertinent to an explosion occurring in a data buoy. In this accident one person was killed. Another accident caused a minor injury to the buoy handler (National Oceanic Atmospheric Association, n.d.). Another accident involving hydrogen build-up in a battery compartment was investigated after a marine science student was killed when using a grinder near the battery compartment of the *SV Concordia* (Australian Transportation Safety Board, n.d.).

In a document produced by Voltaix, Inc., the health effects of hydrogen were identified and discussed. In addition, the document identifies the extremely wide flammability ranges of hydrogen (Voltaix, 1994). The facts gathered from this document were further supported by a report compiled by The International Consortium for Fire Safety, Health, and the Environment.

Information specific to the battery charging process gathered from Zomeworks (Zomeworks, n.d.) and Japlar/Schauer (Japlar/Schauer, 2000) identified the amounts of hydrogen produced during battery charging and the rates at which levels become explosive. These documents also outlined safety procedures for operating battery chargers.

The biological effects of hydrogen were gathered from Voltaix, Inc. MSDS sheets (Voltaix, 1994). Hydrogen characteristics retrieved from EZRESULTS.com also proved to support the health effects of hydrogen. The primary health concern for hydrogen is asphyxiation because it can displace oxygen in a room.

Procedures

Research Methodology

The purpose of this research project was to determine the severity of the risk to the community and develop an effective risk reduction program. The research methodology employed was action-oriented using historical and descriptive methods. It was necessary to evaluate agencies currently protecting “golf cart communities” to determine statistical data and any current risk reduction programs.

Survey Descriptions

The first step in the research was to identify the specific number of potential hydrogen producing sources within the jurisdiction of the VPSD. This project involved two surveys. The surveys were designed to elicit specific information from the survey groups. The first survey conducted involved homeowners within the VPSD jurisdiction. This survey was kept in a yes/no format to encourage all those surveyed to complete the survey easily and quickly. In addition, this survey was conducted during regularly scheduled meetings of large groups to allow for the surveys to be returned in a timely manner. This forum allowed for a significant number of the surveys to be completed and returned. The survey was distributed to 185 residents with 159 surveys returned. This equated to a return rate of 85.94% (Appendix “A”).

The second survey involved emergency services providers responsible for providing services to “golf cart communities”. The agencies surveyed are listed in appendix “C”. This survey was conducted via phone to expedite the return of the information requested and to allow the respondents to expound upon the information provided. In addition, this also allowed for 100% of the surveys to be completed (Appendix “B“).

Interviews

Interviews were conducted with individuals in the battery and carbon monoxide detector manufacturing industries. Phone interviews were conducted with Jeff Day, an environmental scientist with the Nighthawk Corporation. George Kerr of the S-Tech Corporation was also interviewed. Mr. Kerr currently serves as an advisor to the U.S Consumer Product Safety Commission, the American Gas Association, and the Canadian Gas Association. Ms. Nina Bushell from Dicon Global was also interviewed. Ms. Bushell also works as a service technician for Dicon Global. A list of standard interview questions was utilized as a basis for conducting the interviews (Appendix “E”).

Phone interviews were also conducted with Jim Le of the Trojan Battery Corporation, John Bear of the Exide Battery Corporation, and Lee Norman of the Crown Battery Corporation. Each of these individuals serve as environmental scientists for their respective corporations. A list of standard interview questions was utilized as a basis for conducting the interviews (Appendix "D").

Assumptions and Limitations

The literature review identified a significant lack of information pertaining to hydrogen incidents involving overcharging of golf cart batteries. A search of Executive Fire Officer papers provided no previous Applied Research Projects pertaining to hydrogen off-gassing from batteries. The literature review also identified a shortage of research pertaining to accidents involving batteries.

This research project was limited by the available number of emergency services providers responsible for protecting "golf cart communities." Many fire departments have golf courses within their respective jurisdictions which utilize electric golf carts. However, few departments are responsible for protecting a large number of golf carts stored inside of private residences. These private residences are exempt from many of the codes and standards that golf courses must comply with when storing and charging lead acid batteries.

This research project also assumed carbon monoxide detectors to be common in many homes. This assumption was made because the carbon monoxide detector was the device that initially brought this risk to the attention of the VPSD. However, it was discovered that many departments surveyed did not experience a significant number of CO detectors in their respective jurisdictions. This limitation did not become apparent until the survey was begun. Anecdotal information indicates that many of these communities do not have CO detectors in the older residences.

Results

1. **What is the impact of over-charged golf cart batteries to the community?**

    a. What is hydrogen?

According to Voltaix, Inc. hydrogen is a colorless, odorless, tasteless and nonpoisonous gas under normal conditions (Voltaix, 1994). Hydrogen is considered to be one of the alternative fuels of the future. Many national and international leaders have repeatedly addressed the need to find new and cleaner fuel sources to meet the ever-increasing demands of society. President George W. Bush has elevated the significance of utilizing hydrogen as an alternative fuel source by addressing the subject in the State of the Union Address in 2003. President Bush stated *"In this century, the greatest environmental progress will come about not through endless lawsuits or command-and-control regulations, but through technology and innovation. Tonight I'm proposing $1.2 billion in research funding so that America can lead the world in developing clean, hydrogen-powered automobiles."*

In addition to being considered an alternative fuel of the future hydrogen is currently used in a variety of capacities in the manufacturing industry internationally. Hydrogen is used in the manufacture of ammonia and methanol. It is also used to produce fertilizers, glass, refined metals, vitamins, cosmetics, semiconductor circuits, cleaners, lubricants, soaps, peanut butter, margarine, and rocket fuel (EZResults, 2003). Hydrogen is considered to be one of the cleanest and most efficient fuels ever utilized, and this has lead to the increased interest in its use in manufacturing and transportation.

Hydrogen is not only produced in a normal manufacturing process intended to be used for the above mentioned purposes, but it is also created during normal battery charging procedures (International Consortium, n.d.). This hydrogen production can be further exaggerated when battery chargers are allowed to operate for long periods of time. Long charging times can allow the water inside of the battery to boil off and create hydrogen (Japlar/Schauer, 2000). In a 1996 "Marine Technical Note," the United States Coast Guard stated "*even in batteries designed for low hydrogen output, this may occur due to a bad power supply, overcharging, or residual off-gassing. If battery compartment ventilation is inadequate, hydrogen gas will accumulate. Even with a sealed battery compartment, hydrogen gas can leak into the passenger compartment due to equipment failure or the crew's failure to follow proper maintenance procedures."*

b. What are the dangers of hydrogen

Many people are familiar with the use of hydrogen gas in the space industry. Liquid hydrogen is the fuel used to propel the NASA space shuttles into space. In 1985 NASA's space program experienced a major set back when the hydrogen fuel tank on the *Challenger* shuttle exploded. In addition, the *Hindenburg* accident is one of the most memorable events involving hydrogen. In addition to the space industry's usage of hydrogen as a primary fuel source, the United States Armed Forces are a significant user of battery operated devices. The U.S. Navy utilizes large numbers of batteries for operation in submarines and other "submersible vehicles". These batteries and their supporting charging systems operate onboard life support systems. (United States Coast Guard, 1996).

The dangers from hydrogen involve asphyxiation, fire, and explosion. Three conditions must exist to cause batteries and charging systems to form an explosive situation. First, their must be an accumulation of hydrogen gases. Second, a failure to detect the hydrogen gas must exist. Third, there must be a source of ignition (United States Coast Guard, 1996). Hydrogen gas is odorless and colorless, and its flammable limits are between 4% to 74%. The level of hydrogen which will produce an oxygen deficient environment is well within the flammable limits (Voltaix, 1994). This makes the possibility of fire and explosion very real. In addition, the potential of forming and igniting flammable mixtures is higher because the gas easily migrates through small openings, cracks, and crevices. Ignition sources such as electrical sparks, open flames, and static electricity are readily available and are quite common in the residential as well as commercial environment (Calicorp, 1999).

The U.S Coast Guard has recorded at least one incident involving the explosion of hydrogen gases resulting from overnight charging of batteries (United States Coast Guard). The major contributing factors of this explosion were poor ventilation of the battery compartment and the passenger compartment.

The United States fire service has experienced smaller scale explosions involving hydrogen gas and battery operated devices. In December 1992, a firefighter was slightly injured during a training exercise when a flashlight exploded. Another firefighter was injured in January 1995, when a flashlight in his pocket exploded (NIOSH, 2000). Additional incidents involving Automated External Defibrillator (AED) batteries have been recorded. In October of 1999, the Okaloosa Island Fire Department experienced an explosion of a battery inside an AED (NIOSH, 1997).

c. Who is affected?

The dangers exist on a variety of levels. The potential victims include homeowners, firefighters, police officers, and paramedics. The danger to homeowners extends well beyond the confines of the home in which the over-charged battery occurs. The obvious dangers are the loss of life and property within the responsible party's home. The secondary dangers occur from a fire/explosion extending from the property of origin to an exposure property. The Villages is a community of approximately 44,000 residents with a projected population of 104,000 residents (Lester, G., personal interview September 21, 2003).

The Villages residents are in the first line of risk. In the survey conducted by the VPSD, more than 35% of the respondents indicate that they leave their golf cart on charge at all times. 5.19% of the respondents indicated that they did not purchase a battery charger specifically designed for their golf cart. In addition, 4.55% indicate they do not own the battery charger originally purchased with the golf cart (Appendix "A").

Typically the CO detector is designed to activate when the unit detects 150 ppm for approximately 30 minutes. A CO detector exposed to hydrogen gas for 30 minutes at 300 ppm will also cause an activation of the unit (Day, J., personal interview, October 12, 2003). This data was further supported by information Received from Dicon Global. In addition to hydrogen gas, other gases can also cause an activation of a CO detector. Some of these gases include methane @ 500 ppm, Acetone @ 200 ppm, and Toluene @ 200 ppm. (Bushell, N., personal interview, October 12, 2003).

Additional factors may cause the detector to function outside of the normal parameters. CO detectors that are 5 years or older may react at different threshold levels than originally designed for.

The constant exposure to hydrogen gases can also effect the activation threshold levels of the CO detector (Kerr, G. personal interview, October 12, 2003). This information was also supported by information obtained from the Dicon Global Corp. (Bushell, N. personal interview, October 12, 2003).

d. Is hydrogen toxic?

Beyond the obvious danger of fire, explosion, and asphyxiation little data is available indicating the untoward health effects of long-term exposure to the gases given off during the battery charging process. The quantity required to kill a human being is very substantial (EZResult, 2003). NFPA 704 identifies the health effects of hydrogen as being a 0. In addition, OSHA's Permissible Exposure Limit (PEL) and Recommended Exposure Level (REL) are not set due to the fact that hydrogen is considered to be relatively safe below the flammable and explosive levels (Periodic Table of Elements, 2003). Even though hydrogen is viewed as being non-toxic many occupants in homes responded to by VPSD have complained of headaches, nausea, dyspnea, and vertigo.

2. Has another emergency response agency or community experienced a similar situation involving overcharged golf cart batteries?

In conducting phone interviews with fire departments responsible for protecting golf cart communities, it was noted that only one other agency has developed a formal "golf cart charging safety" program. However, this program did not focus on the production of hydrogen from overcharged golf cart batteries. The Golder Ranch Fire District (Orlo Valley, AZ) developed their program as a response to fires involving golf carts and the battery chargers being used. The Peachtree City Fire Department (Peachtree City, GA) did indicate that they had noticed a correlation between overcharged golf cart batteries and carbon monoxide detector activations. However, they have not conducted a study to identify the potential causes. Many survey respondents indicated they had experienced fires involving golf cart fires that had been attributed to electrical shorts (Appendix "B").

3. What needs to be done to mitigate this situation?

Effective risk reduction programs combine emergency response, code enforcement, legislative processes to create and adopt codes, and other types of mitigation efforts (National Fire Academy, 2003). Public education and information programs will need to be designed and implemented to bring the significance of this problem to the attention of the community. In addition, potential engineering controls will need to be investigated, designed, and incorporated into the home construction process. Further efforts will have to focus on local building requirements to include improved ventilation into garages. Hydrogen gas dissipates at an extremely fast rate and simple ventilation is viewed as the easiest method for controlling explosive levels. Battery manufacturers recommend an air movement of 250 degrees across the top of a battery being charged. This air movement can be gained by opening the battery compartment and garage door whenever the golf cart is being charged (Norman, L. personal interview October 16, 2003).

4. **What emergency response procedures exist, or should be implemented, in the event of a hydrogen release?**

Initially, the VPSD must change the response procedures for carbon monoxide detector activation to increase response mode from “non-emergency” to “emergency”. This would be done to provide immediate mitigation efforts in a potentially dangerous situation. The department currently responds to CO detector activations in a non-emergency mode when all occupants have vacated the structure and emergency mode when occupants remain in the structure. Second, the department must add hydrogen detection to its current inventory of gas detection capabilities.

Discussion

This project was chosen because the VPSD has conducted a risk analysis to determine the threat to the community. This assessment identified the fact that while dangers from overcharged golf carts had a low frequency of occurring, but do present a high risk (National Fire Academy, 2003). The instances in which over-charged golf carts have generated a 911 call accounted for only 13% of the carbon monoxide activations in the preceding year (VPSD. Data file). The belief of the department leadership is that even though only one other emergency response agency has experienced similar instances, the threat is significant enough to warrant that a formal risk reduction program be developed.

As this project began many individuals within the field of emergency services have not identified a correlation between CO and hydrogen production from golf cart batteries being overcharged (Appendix "B"). Most of the agencies responsible for providing fire protection services to "golf cart communities" have experienced golf cart fires and attributed these fires to electrical shorts within the golf cart itself. Many of the agencies expressed an interest in re-visiting the investigation of golf cart fires as well as the potential sources of CO alarms in the family residence.

During the research process it became apparent that many of the communities surveyed were significantly older than The Villages, and they did not have CO detectors as a commonplace item in their respective residences. In addition, construction processes in older homes may allow garages in which golf carts are being charged to receive more natural ventilation.

Even though research of other emergency services providers proved unfruitful, a significant amount of data was collected from the marine industry. This data assisted the VPSD in focusing on the significance of the problem and the required solutions. The marine industry uses battery operated devices on a regular basis (United States Coast Guard, 1996). The marine industry data was also relevant in identifying many of the steps necessary to mitigate the potentially disastrous effects of the problem. The increased ventilation of battery charging areas is key to increasing the safety of the residents (NOAA, n.d.).

Often times the data collected and maintained by the private sector (i.e. battery and CO detector manufacturers) is assumed to have been placed into the public for general knowledge. In the *Concordia* accident it was noted in the investigation summary that the operators had placed a significant reliance on another agency to act as the guardian of the industry (Australian Transportation Safety Board, n.d.). The survey conducted of emergency services providers to golf cart communities (Appendix "B") demonstrates that only one of the respondents was aware that hydrogen gas caused a "false positive" reading in CO detectors. Hydrogen gas is regarded as a very dangerous material in an uncontrolled environment and can prove to be very deadly to the typical citizen.

Emergency services providers have typically looked at the possibility of hydrogen off-gassing from batteries as a minimal problem. None of the agencies surveyed have developed a risk reduction program to address the problem of golf carts being overcharged. However, many of the agencies have experienced several fires involving golf carts. This fact can lead one to question whether golf carts having experienced a fire could have been determined to be electrical in origin when hydrogen may have been the culprit.

Recommendations

Addressing this problem must be approached from a variety of angles. The differing methodologies used should include the local news media, the traditional public education and awareness tools, as well as the continued monitoring of the risk. This approach employs a three-pronged PEIR program utilizing education, information, and relations to gain understanding and "buy-in" from the community (National Fire Academy, 2003).

The department must work with the local news media to bring attention to the problem into the public eye. This should include using newspaper articles to emphasize the magnitude of the problem. These articles should be repeated several times throughout the year. In addition to the print media, the department must work with the local television media to create "mini infomercials" highlighting the dangers of over-charging the golf cart batteries and the proper techniques of charging them. The Villages operates its own newspaper, television, and radio stations. The VPSD currently conducts a weekly "safety corner" in the local newspaper as well as a weekly television spot highlighting the information presented in the newspaper article.

The Villages Homeowners Association (VHA) currently conducts a golf cart driving safety program for all residents. This program should be augmented to include a segment focused on safely charging golf carts. The department must also work with the local golf cart sales agencies to assist in the distribution of a “Golf Cart Charging Instructions” brochure (Appendix “E”) to their respective clients when they purchase a golf cart.

The VPSD must change the focus of response to carbon monoxide detector activations from being carbon monoxide only to potentially being either a CO or hydrogen gas emergency. The department currently responds to carbon monoxide detector activations in a non-emergency mode when residents have left the building, and in an emergency mode when residents are still in the building. This response should change to an emergency response on all carbon monoxide detector alarms because of the significant potential of hydrogen gas explosion and fire.

The department must also continue to monitor CO alarm activations and improve data collection. The department currently records CO activations as an alarm response. This data needs to be further codified to reflect a differentiation between actual CO and the presence of hydrogen. Many of the emergency services providers interviewed during this process expressed an interest in the findings of this project. The VPSD should continue to maintain this professional relationship to aid in the collection and exchange of data.

The department currently uses a gas detector for lower explosive limits, carbon monoxide, oxygen, and hydrogen sulfide. The department should augment this detector with a gas detector capable of detecting hydrogen gas. All data from CO activations must be surveyed to include CO detector manufacturers involved, location of the detector in the home, location of the golf cart in the garage, CO reading levels in the home, and hydrogen reading levels in the home.

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Appendix "A"

Survey Questions for Villages Residents

1. Does your household own a golf cart?

   Yes (153) 96.23% No (6) 3.77%

2. Is your golf cart:

   Gas (26) 16.88% or Electric (128) 83.12%

3. Did you purchase a battery charger specifically designed for use with a golf cart?

   Yes (122) 79.22% No (8) 5.19% N/A (24) 15.59%

4. Do you still own the battery charger originally purchased with your golf cart

   Yes (122) 79.22% No (7) 4.55% N/A (25) 16.23%

5. Do you keep your golf cart charging at all times when not in use

   Yes (55) 35.71% No (72) 46.75% N/A (27) 17.54%

6. Have you ever experienced an alarm with your Carbon Monoxide detector?

   Yes (9) 5.84% No (103) 66.88% N/A (42) 27.28%

7. If you experienced an activation of your Carbon Monoxide was it attributed to your golf cart battery?

   Yes (2) 1.3% No (33) 21.43% N/A (119) 77.27%

   Note: 185 surveys issued with 159 surveys returned. Equals 85.94% return

Appendix "B"

Interview Questions Emergency Services Providers

1. What is the population of your "golf cart" community?

• Sun City West, AZ	35,000
• Sun City Anthem, NV	10,000
• Sun City Summerlin, NV	100,000
• Sun City Vistoso, AZ	18,000
• Sun City Roseville, CA	5,000
• Sun City Grand, AZ	25,000
• Peachtree City, GA	35,000
• Sun City Palm Desert Mountain Vista, CA	10,000

2. How many golf carts are in this community (approximately)?

• Sun City West, AZ	25,000
• Sun City Anthem, NV	4,000
• Sun City Summerlin, NV	40,000
• Sun City Vistoso, AZ	9000
• Sun City Roseville, CA	2,000
• Sun City Grand, AZ	15,000
• Peachtree City, GA	11,000
• Sun City Palm Desert Mountain Vista, CA	2,000

3. Has your agency noticed a correlation between carbon monoxide detector activation and golf cart batteries being over-charged?

• Sun City West, AZ	No
• Sun City Anthem, NV	No
• Sun City Summerlin, NV	No
• Sun City Vistoso, AZ	No
• Sun City Roseville, CA	No
• Sun City Grand, AZ	No
• Peachtree City, GA	Yes
• Sun City Palm Desert Mountain Vista, CA	No

4. Has your agency conducted any statistical surveys regarding this issue?

• Sun City West, AZ	No
• Sun City Anthem, NV	No
• Sun City Summerlin, NV	No
• Sun City Vistoso, AZ	No
• Sun City Roseville, CA	No
• Sun City Grand, AZ	No
• Peachtree City, GA	No
• Sun City Palm Desert Mountain Vista, CA	No

5. Has your agency conducted any risk-reduction efforts to address this issue?

• Sun City West, AZ	No
• Sun City Anthem, NV	No
• Sun City Summerlin, NV	No
• Sun City Vistoso, AZ	No
• Sun City Roseville, CA	No
• Sun City Grand, AZ	No
• Peachtree City, GA	Local newspaper stories
• Sun City Palm Desert Mountain Vista, CA	No

APPENDIX "C"

Fire Departments Responsible for Golf Cart Communities

Community	Department
1. Sun City West, AZ	Sun City West Fire Rescue
2. Sun City Anthem, NV	Henderson County Fire Rescue
3. Sun City Summerlin, NV	Las Vegas Fire Rescue
4. Sun City Vistoso, AZ	Golder Ranch
5. Sun City Roseville, CA	Roseville Fire Rescue
6. Sun City Grand, AZ	Surprise Fire Rescue
7. Peachtree City, GA	Peachtree Fire Rescue
8. Sun City Palm Desert Mountain Vista, CA	Palm Desert Fire Rescue

Appendix "D"

Survey Questions for Battery Manufacturers

1. Has your company identified a correlation between Carbon Monoxide detector activations and hydrogen produced by overcharged batteries?

Exide Batteries: Yes, we have received several inquiries lately pertaining to this issues. The hydrogen causes a "false positive" in the CO detector. We have conducted no further studies, but it is something we will be looking at

Crown Batteries: Yes, the hydrogen gases produced during the charging process will give a false reading to CO detectors. Batteries will gas more when water levels are low.

Trojan Batteries: Yes, the cross sensitivity of each detector varies. The hydrogen gas produces the alarm, but sulfuric acid vapors are probably causing the health related complaints

2. Has your company conducted any studies to identify at what rate an overcharged battery can create an explosive environment from hydrogen (i.e. garages)?

Exide Batteries: No

Crown Batteries: No

Trojan Batteries: No

3. Has your company identified any health related issues involving long-term low dose exposure to hydrogen?

Exide Batteries: No

Crown Batteries: No

Trojan Batteries: No

Appendix "E"

Questions for Carbon Monoxide Detector Manufacturers

1. Is it possible for hydrogen gas to give a "false positive" reading to carbon monoxide detectors?

Dicon Global: Yes, more likely when the detector is old or has been exposed to hydrogen for long periods of time.

Nighthawk: Yes,

S-Tech: Yes

2. Has your company conducted studies specific to this issue?

Dicon Global: Yes

Nighthawk: Yes

S-Tech: Yes

3. If so, what levels of hydrogen cause the activation

Dicon Global: 100 ppm

Nighthawk: 150 ppm in 30 minutes. Have experienced hydrogen build up in basements with sump pumps

S-Tech: 150 ppm. Less alarms with CO detectors manufactured after October 1, 1998

Appendix "F"

Golf Cart Charging Instructions

Instructions for your safety.

DANGER! RISK OF BATTERY EXPLOSION FROM HYDROGEN GAS. MAY RESULT IN BLINDNESS, SERIOUS INJURY, PERMANENT DISFIGUREMENT AND SCARRING.

Batteries generate explosive hydrogen gas, even during normal operation. They can explode under normal operating conditions. They can explode under abnormal conditions, such as jump starting, or if short-circuited by a tool. They can explode in a parked car or sitting on a table.

To help reduce the risk of these dangers and injury, it is of the utmost importance that each time before charging your golf cart, you read and understand all warnings and instructions by the golf cart and battery manufacturer.

TO HELP REDUCE THIS RISK PLEASE FOLLOW THESE RECOMMENDATIONS:

Wear Personal Protective Equipment - ALWAYS wear complete eye protection. This means eye protection that covers the entire eye area.

Avoid Flames and Sparks Near Battery and Fuel

- **ALWAYS** keep flames, matches, lighters, cigarettes or other ignition sources away from battery.
- **DO NOT** put flammable material under the golf cart when charging.
- **ALWAYS** plug charger into an electrical outlet **AFTER** all connections have been made.
- If necessary to remove battery from the golf cart, **ALWAYS** turn off all accessories in the cart. Then **ALWAYS** remove grounded terminal (connected to car frame) from battery first.
- A tool touching both battery posts or battery post and car metal parts is a short circuit and will spark. When using metal tools on or near battery be extra cautious to reduce risk of short circuit, possibly causing a battery explosion. **DO NOT** drop a tool on battery.

Reduce Explosive Gas (hydrogen)

- Before connecting charger, **ALWAYS** add water to each cell until battery acid covers plates to help purge extra gas from cells. **DO NOT OVERFILL**. Battery acid expands during the charging process. After charging fill to level specified by battery manufacturer. For a battery without removable caps (maintenance free battery), carefully follow manufacturer's instructions on charging.
- Some sealed maintenance free batteries have a battery condition indicator. A light or bright colored dot indicates low water. Such a battery needs to be replaced, not charged or jump started.
- Charge battery with caps in place. **DO NOT** pry caps off sealed batteries.
- **NEVER** charge a golf cart when you are not home to monitor the charging process
- Open garage doors when charging the golf cart. All battery charging should be conducted in a well-ventilated area before and during the charging process..
- **NEVER** charge in a closed-in or restricted area.

Stay Away From Battery When Possible

- **NEVER** put face near battery.
- **ALWAYS** locate charger as far from the golf cart as the cord permits.
- **ALWAYS** keep other people away from the battery.

Avoid Contact With Battery Acid

- Battery posts may have **acid corrosion**. **DO NOT** get corrosion in your eyes. Avoid touching eyes while working near battery.
- **ALWAYS** use a battery carrier. Carrying a battery by hand may put pressure on its ends, causing acid to be forced out vent caps.
- **ALWAYS** have plenty of fresh water and soap nearby in case battery acid contacts eyes, skin or clothing. If battery acid contacts skin or clothing, wash immediately with soap and water. If acid enters eye, immediately flood eye with cold running water for at least fifteen (15) minutes and get medical help immediately.
- In very cold weather a discharged battery may freeze. **NEVER** charge a frozen battery. Gases may form, cracking the case, and spray out battery acid. See BATTERY DATA table.

Avoid Overcharging Batteries

- The non-automatic (manual) battery charger models can overcharge a battery if left connected for an extended period of time, resulting in loss of water and creation of hydrogen gas.

Follow Other Manufacturers' Recommendations

- Before using charger, read all instructions for, and caution markings on: (1) charger, (2) battery, and (3) related product using battery. Follow their recommended rate of charge.
- **DANGER - NEVER** alter AC power cord or plug provided.

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