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Evaluation of an Incident Involving a Black Iron Pipe Gas Fuel Distribution System

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1.0 INTRODUCTION

On December 4, 2012, RTI Group LLC (RTI) was asked to comment on an incident involving a black iron pipe failure and resultant catastrophic explosion and fire, which highlight some of the benefits and vulnerabilities of the use of black iron pipe and how a corrugated stainless steel tube would have averted the disaster.

2.0 VILLAGE GREEN APARTMENTS EXPLOSION AND FIRE

2.1 Background

On June 16, 2001, an explosion occurred at the Village Green Apartments complex in Hatboro, Pennsylvania. The apartment complex had been subjected to local flooding due to heavy precipitation from tropical storm Allison. It was reported that a gas-fired clothes dryer located in the basement of apartment building A was displaced due to water suddenly and rapidly entering the basement. Subsequently, the gas utility pipe servicing the dryer failed at a joint and provided unrestricted flow of natural gas into the basement. After a period of nearly three hours, an explosion occurred, resulting in severe property damage and some personal injuries. Subsequently a fire developed, resulting in further property damage, several personal injuries, and six fatalities.

At the time, PECO Energy Inc. (PECO) retained an engineering consulting firm to investigate the cause of the explosion, document the accident site, and provide technical consultation. The firm assigned the matter to Richard B. Loucks, Ph.D., P.E.[1] and Mr. Mel Schroeder, who visited the accident site on July 6, 2001. Given his involvement in the 2001 investigation, RTI assigned Senior Mechanical Engineer, Dr. Loucks to the current matter.

2.2 Village Green Apartments Accident Site Inspection

The Village Green Apartments explosion site was inspected on July 6, 2001. At that time, the site was documented by written field notes and photographs. The complex, owned and operated by the Scully Co., consists of eight structures containing two buildings, each with four units. Each building was identified by a letter and the apartment by the building letter and the unit number (A1, D4 etc.). The buildings affected by the explosion were buildings A, B, and C, seen in **Figure 1** where buildings A and B were within the northern most (upper part of the photograph) structure. The left hand image, from April 1999, provides a clear overhead view of the complex, free from tree cover. The July 2001 image shows the partially demolished remains of Buildings A and B. The front of buildings A and B can be seen in **Figures 2** and **3**. The images in **Figures 2 and 3**, each made from several images and rendered into a composite, show some of the damage caused by the explosion and fire. The site had been unavoidably disturbed by the local authorities while conducting their investigation and in retrieving the remains of the deceased.

[1] Dr. Loucks left the firm in April 2003.

Figure 1. Aerial view of Village Green Apartments complex, April 24, 1999 and July 16, 2001. Note: Images are oriented with north to the top.

Figure 2. View of the front of building A – composite of several photographs.

Figure 3. View of front of building B – composite of several photographs.

2.3 Building Construction

Each structure was comprised of two connected buildings. Each building had three stories with a basement. Each building was divided by an area of common egress. The common area provided split stair access on the front and back side to the multi-story units and basement. The basement contained four rooms of the same dimensions as the units immediately above, and was partially exposed above grade. The living units were arranged four to a floor. The unit numbers were as follows: Unit 1 was at the front and left of the entrance, Unit 2 was to the right of the entrance, Unit 3 was behind Unit 2, and Unit 4 was behind Unit 1. On the second floor, the numbering repeated the same counter-clockwise order starting with Unit 5

There were several windows to the basement that varied in size. As seen in **Figure 4**, the larger windows extended below the basement wall mid-height. The larger windows were missing their glass. Some of the smaller windows exhibited signs of exposure to outside pressure as they were deformed around their frames; however, the glass on the smaller windows was still present in the frames. On the first and second level were four units on each level. On one side of the common way were two-bedroom units; on the other side were one-bedroom units. The attic was unoccupied.

Figure 4. View from the northern front basement room in building A. Note the two sizes of windows, the larger window having failed during the storm.

The structures were constructed from concrete masonry unit (CMU) with a brick façade exterior, sheet rock interior with two-by-four wood stud framing. The units were separated by a CMU fire wall if not by the common area. The floors were constructed by hollow reinforced concrete planks, supported by the CMU walls on the front, center, and back of the structure. Each unit was serviced by two wall penetrating air conditioners in the two-bedroom units and one air conditioner for the one-bedroom units. Each unit had a single gas burning stove and oven. Heat, from hot water baseboard radiant heat, and hot water were supplied from a central boiler room in building C. The interior partition walls were constructed of two-by-four wood stud frame covered by sheet rock. There was no common forced ventilation system in the building.

The elevation of the sills of building B and building C were discontinuous. The sill for building B was approximately 5 to 6 inches higher than that of building C. The same was true for the window frame elevations, indicating that building B was higher than building C. Building A and Building B were discontinuous horizontally, with building A located approximately 2 ft forward of building B, however their floors, sills, and window frames were at the same elevations. Therefore, the first floor level of building A is approximately 5 inches higher in elevation than the first floor level of building C.

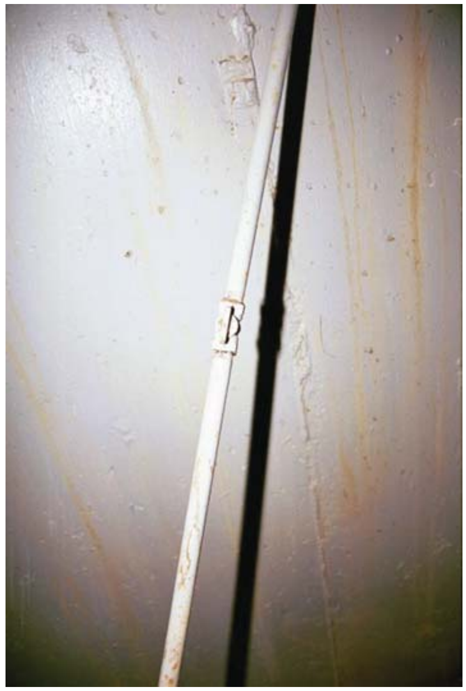
2.4 Subject Laundry Room

The laundry room in building A was found to have a mop sink, electric washer, a gas-fired dryer, and a folding table, as seen in **Figure 5**. A section of the wall between the gas dryer and the folding table had failed. The dryer was displaced and rotated from the wall. The mop sink, washer, and folding table remained in, or close to their original locations. Brown silt was found within the fluorescent light fixtures, indicating the room had at one time been completely submerged. The ceiling comprised of the reinforced concrete hollow planks, had seams with approximately 1/8- to 1/4-inch gaps.

Figure 5. View of laundry room in building A.

The natural gas fuel for the dryer was fed from a black iron pipe tee tap in the fuel gas main running across the basement ceiling. A 1-inch line dropped from the tee tap about 12 inches, turned 90° horizontally to the right and towards the wall (facing the wall) though a 1-inch to 3/4-inch reducer and a 90° elbow to a 3/4-inch line (**Figure 6**). The 3/4-inch line ran horizontally towards the wall for about 36 inches, turned 90° downwards through a street elbow (**Figure 7a**). The 3/4-inch line ran about 45 inches, through a shut-off valve (**Figure 7b**), to a fitting for the 1/2-inch corrugated steel flexible pipe line (**Figure 7c**). The flexible line was approximately 36 inches in length, and terminated into a 3/4-inch 90° iron pipe elbow fitted to a 3/4-inch black iron pipe stub 6 inches in length coming off the back of the dryer (**Figure 8**).

Figure 6. View of upper elbow and gas pipe break.



a) b)

c)

Figure 7. Closer view of subject pipe line.

Figure 8. View of corrugated steel flexible line connecting to stub on dryer.

The dryer was a Whirlpool, Model Number CG2951XYW4, Serial Number MJ3003953, Type D433-NAT-1205006-CS22. The dryer was rated at 22,000 BTU/hr with a gas manifold pressure of 3 iwc. The recommended inlet pressure range was between 5.2 to 10.5 iwc. The unit was specified for natural gas, and possessed the symbol of the American Gas Association design certification. A sticker affixed to the coin slot indicated that CALECO would provide service and would respond to emergencies.

The black iron pipe above the dryer had failed at the 3/4-inch 90° street elbow near the ceiling. It was specifically the black iron pipe section, not the elbow fitting, which failed at the thread outside the upstream side of the elbow, as seen in **Figure 9**. There was no evidence to show that there ever was a pipe anchor used to secure the vertically running section of black iron pipe to the wall. Additionally, the dryer was not secured by tracks or any other means. The only method used to secure the vertical run of black iron pipe was a pipe strap fixed to a section of electrical conduit near the elbow. The area of the black iron pipe break opening exceeded the pipe flow cross sectional area, allowing unrestricted release of fuel gas into the laundry room after the failure.

Figure 9. Close view of failure site and hanger.

The laundry rooms of buildings B and C were inspected to discover the method used for securing the dryer gas pipe. Although these buildings' basements were also flooded, there were no reported gas leaks. The dryer in one building was also displaced, and the adjacent wall also suffered damage; however, the pipe was intact despite the lack of a pipe anchor on the vertical run (**Figure 10**). The laundry room of another basement revealed that the dryer had been slightly displaced (**Figure 11**). The pipe servicing the dryer in this building did have a single pipe anchor on the vertical run and remained undisturbed. In all cases, the flexible corrugated steel tube connecting the dryers to the black iron pipe distribution system remained intact.

Figure 10. Dryer gas pipe without anchors.

Figure 11. Laundry room in building where the gas pipe was anchored.

The explosion that occurred on June 16, 2001 was the result of liberated and fugitive natural gas having accumulated over a significant period of time within sections of Building A, and having been ignited by some competent ignition source. The ensuing explosion caused massive property damage, as seen in **Figures 1, 2 and 3**, as well as personal injuries and several fatalities. In short, the release of fuel gas resulted in a catastrophe.

The release of fuel gas was due to a breach of a section of black iron pipe that was subjected to inappropriate loading forces from the displacement of an appliance affected by a severe natural event. The displacement of the appliance induced a stress on the black iron pipe causing the pipe to fail. Had the fuel gas distribution system been constructed from CSST rather than black iron pipe, the displacement of the dryer would likely not have caused a fracture and breach in the distribution system, the fuel gas would not have been liberated, and the explosion would not have occurred. The flexibility of CSST would have allowed the fuel gas distribution system to have tolerated the large displacement of the appliance. The conclusion that a CSST line would have survived this event is demonstrated by the fact that the flexible gas appliance connection tubing, a product similar to CSST, between the subject appliance and the black iron pipe distribution system remained intact and connected after the flooding and explosion.

The fracture of the black iron pipe was clearly due to several factors: the area had been affected by a tropical storm causing the local creek to rise and flood the apartments; the flooding into the basement had displaced the unsecured dryer; and the black iron pipe was not properly secured with wall anchors, allowing free range of motion of a distribution system not designed for such displacements.

3.0 SUMMARY

One detriment of black iron pipe is its susceptibility to corrosion. Corrosion reduces the strength of the pipe, necessitates substantial over-design for the intended purpose in order to achieve an acceptable life span of the product, can lead to odorant fade, and is responsible for the majority of gas fuel leaks. There are other problems with black iron pipe stemming from its inherent rigidity and tendency to exhibit minimal deformation before fracture. Excessive displacement causing inappropriate loading forces can lead to catastrophic failures of the pipe which then result in massive releases of gas fuel. The flexibility of CSST, its corrosion resistance, the simplicity in installation, and its lighter weight all lead to an overwhelming improvement in the safety and hazard containment of fuel gas within a structure.

4.0 CONCLUSIONS

Based on the foregoing investigation and analysis, to within a reasonable degree of engineering certainty, RTI concludes:

1. The proximate cause of the explosion incident was from a failure of a black iron pipe servicing a natural gas-fired dryer in the basement of building A at the Village Green Apartments.

2. The black iron pipe failed when flood waters rushed into the basement and displaced the dryer.

3. Some of the fugitive gas released from the pipe eventually accumulated to explosive levels.

4. The accumulated gas was ignited by a competent ignition source resulting in an explosion and subsequent fire.

5. The elements that led to the failure of the black iron pipe would not have resulted in the failure of a CSST based system because:
   - The movement of the black iron pipe caused by the displaced dryer would have been accommodated by the flexibility of CSST. The black iron pipe fractured instead.
   - Failure to properly anchor the black iron pipe induced catastrophic stress at the threads when the dryer was displaced. A CSST system that would have been equally inadequately anchored would simply move with the dryer.
   - Corrosion contributed to the weakening of the black iron pipe. CSST is corrosion resistant, and corrosion would not have been a factor in a CSST based system.

6. The flexible connector present on the subject dryer was intact at the time of the inspection, and provides insight as to the survivability of a CSST based system under the adverse conditions encountered during the flood.

RTI reserves the right to amend or supplement this report and its conclusions should additional information become available.

Respectfully submitted,

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