American Gas Association
Safety & Occupational Health Committee

Natural Gas Workers and Natural Gas Fires
Observations and Analysis of Heat Intensity, Escape Time, Extinguish Time and Flame Resistant Garments

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Xcel Energy  Washington Gas Light Co.
ONE Gas, Inc.  Avista Utilities
Vectren Co.  Consolidated Edison, Inc.
UGI Utilities Inc.  Chesapeake Utilities Co.
Columbia Gas of PA – NiSource  Questar / Dominion Energy
National Fuel Gas Company  DuPont Company
Problems:

- No consensus standards for PPE
- Hazards are unquantified
- Lingering industry questions
Solutions:

• Quantify the Hazards
• “Slay the FR Dragon”
Hazards of Natural Gas Fires

Heat Intensity + Exposure Time
Four Unique Studies:

• Escape Time
• Extinguish Time
• Heat Intensity
• FR Garment Testing
Available at the American Gas Association Website at:
https://www.youtube.com/watch?v=FJoi1TyvhtI&feature=youtu.be
Four Unique Studies:

• Escape Time
• Extinguish Time
• Heat Intensity
• FR Garment Testing
Escape Time Testing

**Purpose**
To understand the time required for a worker to escape an excavation.

**Scope**
Establish the time necessary for workers to move a safe distance away from a fire.
**Three variables:**
- Excavations
  - 4’ deep sloped
  - 4’ deep w/shoring box
  - 6’ deep w/shoring box
  - 4’ deep pit w/concrete walls and sand bottom
- Demographics - 5 different employees
- PPE – 5 different configurations
  - standard workwear
  - lightweight FR PPE
  - heavyweight FR PPE
  - heavyweight FR PPE with added respirator configuration
  - welding gear

**Starting Conditions:**
- Worker on one knee at a buried pipe within the excavation
- Workers were engaged in simulated job activities
- Stopwatch begins with the “Go” command
- Ladder used in the 6’ excavation as the escape mechanism

**End Condition:**
- When the worker crosses a point 10’ away from the pipe centerline.
**Greatest Learnings**

- Based on observations, it appears 5.4 seconds to 6.8 seconds is typically required to escape from excavations.

- Personnel demographics resulted in high escape time variability.

- The deeper the excavation, the longer the escape time.

- It appears restricted vision, in this case as a result of a respirator, caused test subjects difficulty in looking down to find the 1st step on the ladder. Missteps increased escape time by approximately 1 second.
Fire Extinguisher Time Testing

**Purpose**
To understand the time it may take a standby person to extinguish a fire in an excavation.

**Scope**
Create excavation fire scenarios and measure the time to extinguish
**Five Variables:**
- Dry powder-type CO₂ fire extinguishers, 20# and 30#
- Two powder agent types
  - Sodium bicarbonate based
  - Potassium bicarbonate based
- Demographics – 4 different workers
- Excavation Depth – 4’ and 6’ excavations
- Leak scenarios – 7/8” diameter hole at 12” WC and 3/8” diameter hole at 55 psi

**Starting Conditions:**
Worker in full FR PPE including balaclava, full visor, hardhat and gloves
Standing at a 10’ distance upwind from leak location
Fire extinguisher upright on ground next to worker
Fire initiated within the excavation
Timing starts with a “Go” command or the onset of combustion
Once an extinguisher’s CO₂ cartridge was activated, the extinguisher was re-used until empty; in these circumstances, workers simulated depressing the activation button

**End Condition:**
Test timing ended when flames were no longer visible
Extinguish Time

Total including trainer and outlier is 5.79 +/- 0.44
Total excluding trainer and outlier is 6.36 +/- 0.71
Greatest Learnings

- Once powder flow was initiated to the fire, the fire quickly went out during every test. There was no significant difference in time needed to extinguish a fire between the two extinguisher weights or powder types. Despite the broad range of variables involved in the tests, times required to extinguish fires were consistent.

- Operator error was the dominant source of variability in times required to extinguish fires. With the operator error data removed from the calculation, average extinguishing time was 5.97 +/- 0.24 seconds. With operator error data included, average extinguishing time was 6.36 +/- 0.71 seconds.
Fire Intensity Testing

Purpose
To measure the intensity of natural gas-fed fires in excavations for typical leak scenarios defined by AGA member companies.

Scope
Build instrumentation system, create excavation scenarios, run trials.
Three variables:
- Excavations
  - 4’ deep unshored
  - 6’ deep w/shoring box
- Two leak scenarios
  - 12” WC with a 7/8” diameter hole
  - 55 psig with a 3/8” diameter hole
- Burn times- 4, 6 and 8 seconds

Starting Conditions:
- sensors placed at key locations:
  identified by infrared imagery to be high heat areas
  position of worker in the excavation and standby person
- Leak located on the bottom of 4” pipe in each situation
- Pilot light lit within excavation prior to introduction of fuel
- Hi-resolution infrared camera and video equipment positioned to capture data

End Condition:
- Fuel supply ended at test time conclusion
The heat intensity reported is the highest heat intensity observed by any sensor during a specific test
4 ft excavation 12 inches wc
Greatest Learnings

- With relatively few exceptions observations confirmed heat intensity in typical excavations fires was 2 calories/cm²-second
- Within the excavation the highest heat intensity was observed at approximately 3’ off the floor of the excavation
- Outside the excavation the highest heat intensity occurred downwind of the excavation
FR PPE Garment Testing

Purpose/Scope:
• Use fire exposure times in the lab based on observations of escape time and fire extinguishing testing
• Use fire intensity of 2 calorie/cm2-second in the lab based on observations of fire intensity testing
• Report predicted body burn of various FR garments used by AGA members (all garments provided by AGA members)
• **2 Garment Ensembles**
  - With 100% cotton L/S
  - Without 100% cotton L/S

• **3 Garment Materials**
  - FR treated cotton
  - FR blends
  - Inherently FR

• Coveralls only; no FR rainwear, pants, shirts, etc.
• 99 tests completed in UL certified lab
• All tests witnessed by AGA members
• Burn times: 4, 6 & 8 seconds
• Predicted burn injury recorded for ea. test
Key Observations from Burn Testing:

- Significant differences in predicted body burn between garments and materials
- Significant differences in garment/material integrity after exposure to flame
Some Predicted Fatality Rates Exceeded 50%

### Fatality rate from burn injury study

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2015 American Burn Association Study
100% Cotton Long Sleeve Shirt Doubles Protection of FR Garments
One FR garment system resulted in < 10% body burn @ 8 second exposure
16.9 oz./sq. yd. (9.4 oz./sq. yd. quilting plus 7.5 oz. outer layer) inherently FR material

16.9 oz./sq. yd. quilted FR coveralls
Burn Test Observations:

- Stationary mannequin; no movement
- Some garments became brittle/broke open at 6 & 8 seconds
- Some garments crumbled during removal
- Significant smoke generation observed from blend materials
**Burn Test Observations:**

- Garment fit is critical (15% difference in predicted body burn)
- Performance of blends & FR-treated cotton garments was inconsistent; garment weight alone is not a reliable predictor of performance
- When normalized for fabric weights, inherently FR materials resulted in less predicted body burn than treated FR cottons or blends

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**Grand Average Performance - Normalized - With Long Sleeve Shirt**

- Inherents With Long Sleeve Shirt
- FR Treated Cottons With Long Sleeve Shirt
- Blends With Long Sleeve Shirt

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**Grand Average Performance - Normalized - Without Long Sleeve Shirt**

- Inherents Without Long Sleeve Shirt
- FR Treated Cottons Without Long Sleeve Shirt
- Blends Without Long Sleeve Shirt
Conclusions:

• Solely relying on escape time is not prudent
• Relying on extinguish time can be risky
  - Worker skill/experience matters
  - Starting position should be considered
• Excavation depth matters
• Worker agility matters
Learnings from FR Garment Testing:

- Lab conditions are similar to field
- 50+% predicted body burn for some garments
- Adding 100% cotton long sleeve shirt doubles protection of all FR tested
Ounce-for-ounce Inherently FR Provides More Protection

Grand Average Performance - Normalized - With Long Sleeve Shirt

- Inherents With Long Sleeve Shirt
- FR Treated Cottons With Long Sleeve Shirt
- Blends With Long Sleeve Shirt

Predicted Body Burn Multiplied By Avg. Weight

- 4 seconds: 0, 9.15, 8
- 6 seconds: 52, 155.5, 120
- 8 seconds: 108.5, 247, 272
Data Enables Informed Decisions
Related to Procedures & PPE

White paper available on AGA website:
“Natural Gas Workers and Natural Gas Fires”
Thank You

Philadelphia Gas Works
Xcel Energy
ONE Gas, Inc.
Vectren Co.
UGI Utilities Inc.
Columbia Gas of PA – NiSource
National Fuel Gas Company

Spire Inc.
Washington Gas Light Co.
Avista Utilities
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