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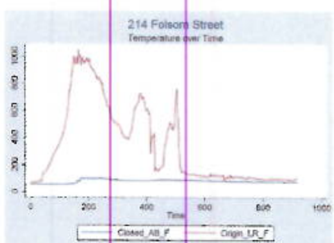
Life safety first fire strategies



Significance of the closed door

Following his research into residential fires, Fire Chief Marion F Blackwell Jr MS CFO EFO FIFireE reports on why the findings require a change in rescue tactics and public fire education

The purpose of this experiment was to challenge the Fire Service theory that when a structure fire exceeds 537 °C (1,000 °F) and when all combustible material ignites (flashover); there are no areas in the home that are humanly survivable.

Data was captured by scientists employed by the National Institute of Standards and Technology. All instruments were calibrated prior to conducting the tests and care was taken to control variables to provide reliable, valid and replicable data. Variable data was analysed utilising regression analysis.

The data reveals that rooms with doors open were not survivable until late in the fire event, which was too late to rescue the victim. However, rooms with doors closed remained survivable throughout the fire event.

These results call for a change in rescue tactics and public fire education. Victims who cannot find a tenable escape route can retreat to an uninvolved room and close the door and remain there until firefighters can suppress the fire and then effect rescue. This is a departure from tactics that resulted in immediate rescue attempts which exposes the firefighter and victim to the extreme temperatures and lethal gases.

Additionally, public fire education will need to be updated to include the option of retreat and shelter in place. Due to the rapid temperature increase exhibited by the current furniture, it may also be prudent to sleep with bedroom doors closed, decreasing the sleeping residents' risk to extreme temperature and toxic gas exposure prior to discovery of the fire.

Theory and Expectations

From January 22 to January 31, 2013, Fire Service professionals and the National Institute of Standards and Technology burned eight single family residences to test different theories held true by the Fire Service. These homes were located on Folsom Street in Spartanburg, South Carolina.

My research question dealt specifically with houses at 214 and 215 Folsom Street. Each structure was burned with identical fuel packages and each room's temperature data was captured at ceiling level and each one foot increment until the sensors reached the floor. Temperature readings were captured in Celsius every second and the burns lasted approximately 15 minutes to achieve uniform heat and gas levels.

A widely held Fire Service theory is that when a structure fire exceeds 537°C (1,000 °F) when all combustible material ignites (flashover), there are no areas in the home that are humanly survivable[1,2]. Test 1 in each structure is designed to test this theory with 214 Folsom Street Test 1 using a ventilation limited fire and 215 Edson Street Test 1 using a ventilated fire with all rooms open except the front bedrooms in both tests and an additional rear bedroom in Test 1. The results of this analysis hold extreme implications for the Fire Service. Rescue techniques and fire education are formed using this widely held assumption.

If the Fire Service arrives to a fully involved house fire with victims trapped, dangerous rescue attempts are made to try to reach the victim. If a victim is located, he or she is removed via the same route as the firefighter enters, thus exposing the victim to extreme temperatures and lethal gases [1,2]. If the theory does not hold true, then victims in the open exposed area are already deceased, so any rescue attempt is futile; but victims in areas with closed doors can remain in those areas of refuge until the fire is suppressed prior to removal. Thus the victim is egressed through a cooler and less lethal environment.

Current fire education teaches to have two exit routes, get low under the smoke: "get out and stay out" and stay at a pre-determined meeting place[3]. The Fire Service does not focus on what to do if the exits are blocked. If the current theory does not hold, additional fire education needs to be added to the current curriculum. If the egress is untenable, then the victim should be instructed to close the door, stay low to the floor, move to an exterior window if available, open and place an item in the window such as a pillow case or towel, and reclose the window on the item. Rescue will be initiated from the window instead of the interior environment. If no exterior window is available then stay in the room with the door closed and you will be removed after the fire is suppressed.

Public safety dispatchers are trained to take call information and process this information for fire department dispatch. Fire dispatchers receive no formal training on instructions to a trapped occupant of a residential structure fire. Most dispatchers will 'ad lib', telling the caller to exit the home and stay out. These same dispatchers are at a loss to provide information when the occupant informs them they are trapped and cannot get out.

If theory does not hold true, a simple instruction of 'get in the room furthest from the fire, close the door, and place something in the window to alert our firefighters where you are and reclose the window. I will inform the firefighters to look for the marked window' could be the difference necessary to save a life.

Firefighters are trained to attempt self-rescue in event they are lost in a burning structure. This leads to firefighters moving around in an extreme fire environment trying to locate an exit. Many perish during these attempts due to thermal insult and depletion of the air in the self-contained breathing apparatus.

If theory does not hold true, the Saving Our Own programme should be modified to provide firefighters the ability to recognise an untenable environment at which time the firefighter should locate a room remote from the products of combustion. The firefighter should then close the door, notify command of his location, conserve air, and wait for rescue. If there is a window in this room, the firefighter should place something in the window to signal his location and reclose the window to minimise air movement under the door.

I hypothesise that a closed door will impact the survivability of a victim's survival, thus disproving the currently held Fire Service theory and increasing the probability of alternate hypothesis being true.

Hθ: Once the structure's environment reaches an average temperature of 1,000°F, then no life tenable spaces remaining in the structure.

Ha: Once the structure's environment reaches an average temperature of 1,000 °F, then rooms with closed doors will have life tenable space while rooms with open doors will not have life tenable space.

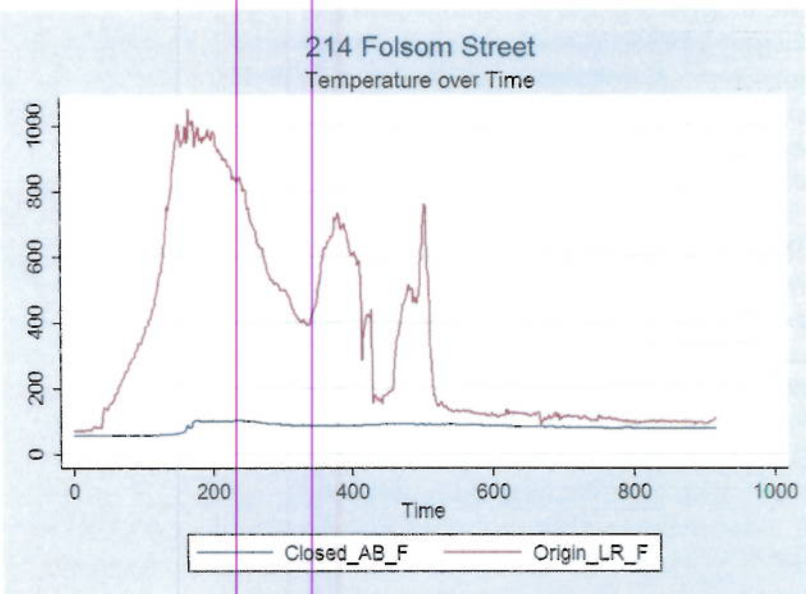
Data Description

The data was captured by scientists employed by the National Institute of Standards and Technology. All instruments we calibrated prior to conducting the tests. Thermocouples were installed in the center of each room in one foot increments from ceiling to floor. Data from the thermocouples were taken every second during the test. All tests were videoed by eight cameras located inside and outside the structures for historical purposes and to allow accurate recreation of the tests by other scientists.

Identical fuel packages were purchased from one furniture vender and utilised to control the fuel loading variable. The fuel package consisted of one microfiber couch, two microfiber chairs, one coffee table, two end tables and two lamps. A newspaper was placed on the couch nearest the exterior wall and ignited remotely with an electric match. The identical fuel packages controlled the fuel load variable to eliminate dissimilar fuel packages from influencing fire growth, thus influencing the test data captured.

The houses were identical floor plans built circa 1930. These homes were built by Spartan Mills with lumber cut from the site. These homes were issued to workers moving from the country into the city to work in the cotton mill. The homes were built with true dimensional lumber with wood siding and asphalt shingle roof. The shingles were removed prior to the burning of the structure. The identical floor plans controlled the structure variable to eliminate a dissimilar structural layout from influencing the fire behavior, thus influencing the test data captured.

Test 1 (214 Folsom Street) was conducted while limiting the ventilation of the structure. All exterior windows and doors remained closed during the testing process. Once the electric match was ignited in Test1, the room of origin (Origin_LR_F) was over 130°F in 44 seconds while the bedroom (Closed_AB_F) was 57°F. Maximum temperature of 1,052°F was attained in 167 seconds (two minutes and 47 seconds) and bedroom (Closed_AB_F) was 83°F. Maximum temperature reached in bedroom (Closed_AB_F) was 103°F at 180 seconds (three minutes).



Test 2 (215 Folsom Street) was conducted while allowing ventilation of the structure. Two exterior windows and the front door were open during the testing process. A similar result is observed in Test 2. The room of origin (Origin_LR_F) was over 130°F in 35 seconds while the bedroom (Closed_AB_F) was 48°F. Maximum temperature of 1,436 °F was attained in 140 seconds (two minutes and 20 seconds) and bedroom (Closed_AB_F) was 51 °F. Maximum temperature reached in bedroom (Closed_AB_F) was 64 °F at 533 seconds (eight minutes and 53 seconds).

I compared the data from the two test burns between the rooms with open interior doors to the rooms with closed interior doors to see if there is a statistical difference and if the room environments could sustain life.

Hθ: Once the structure's environment reaches an average temperature of 1,000°F, then no life tenable spaces remaining in the structure.

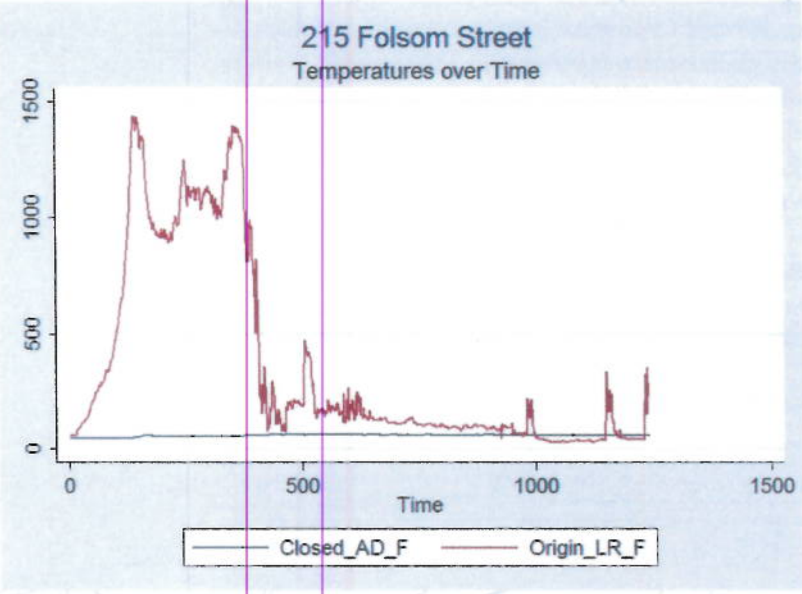
Ha: Once the structure's environment reaches an average temperature of 1,000°F, then rooms with closed doors will have life tenable space while rooms with open door will not have life tenable space.

Data was collected from five rooms via eight thermocouples per room. For the purposes of my model, I chose the front bedroom with a closed door and the adjacent living room with open doors. The living room was the room of fire origin. The thermocouple at 0.91mBC (metres below ceiling) was selected because it was four feet from the floor. Current fire education teaches victims to crawl under smoke, so crawling for even the largest person would be below four feet from the floor. Temperature was collected in Celsius, but I converted this to Fahrenheit to facilitate a better understanding of the temperature readings.

Regression Analysis of Temperature, Time, and Door Position Model

The model's dependent variable is temperature. Survivable temperature is defined as 130°F as this temperature creates third degree burns and irreparable respiratory damage. I created one data column (Time_F) with the temperature from each room. In test 1 (214 Folsom Street) the first 917 data points are from the closed door bedroom (Closed_AB_F) and the last 917 data points from the living room (Origin_LR_F). In test 2 (215 Folsom Street) the first 1,241 data points are from the closed door bedroom (Closed_AD_F) and the last 1,241 data points from the living room (Origin_LR_F).

The model's first independent variable is time. I created one data column (time_01) with the time in seconds from 0 until the end of the test from each room. In test 1 (214 Folsom Street) the first 917



seconds (time) are from the closed door bedroom and the last 917 seconds (time) from the living room. In test 2 (215 Folsom Street) the first 1,241 seconds (time) are from the closed door bedroom and the last 1,241 seconds (time) from the living room.

The model's second independent variable is door. I created one data column (door) with the door open = 0 and the door closed = 1. In test 1 (214 Folsom Street) the first 917 data points are door = 1 (AB_Door) are from the closed door bedroom and the last 917 data points are door = 0 (Origin_LR) from the open door living room. In test 2 (215 Folsom Street) the first 1,241 data points are door = 1 (AD_Door) are from the closed door bedroom and the last 1,241 data points are door = 0 (Origin_LR) from the open door living room.

Model Findings

Regression Temperature, Time, Door – 214 Folsom Street

214 Folsom Street	(1)
	Temp_F
VARIABLES	Temp_F
Time_01	-0.308***
	(0.0184)
Door	-261.9***
	(8.824)
Constant	485.3***
	(14.98)
Observations	1,834
R-squared	0.400

Robust standard errors in parentheses
*** p<0.001, ** p<0.001, * p<0.05

This regression model reveals that for every second of time elapsed, temperature decreases -.307806 at the .001 level and is statistically significant as the 95 per cent CI does not cross 0. Door is negatively associated with temperature by a coefficient of -261.9466 at the .001 level and is statistically significant as the 95 per cent CI does not cross 0. R2 is .40 and the model explains 40 per cent of the variation in the dependent variable.

Regression Temperature, Time, Door – 215 Folsom Street

215 Folsom Street	(1)
	Temp_F
VARIABLES	Temp_F
Time_01	-0.370***
	(0.0162)
Door	-297.9***
	(10.72)
Constant	586.6***
	(18.52)
Observations	2,482
R-squared	0.358

Robust standard errors in parentheses
*** p<0.001, ** p<0.001, * p<0.05

This regression model reveals that for every second of time elapsed, temperature decreases -.370184 at the .001 level and is statistically significant as the 95 per cent CI does not cross 0. Door is negatively associated with temperature by a coefficient of -297.8641 at the .001 level and is statistically significant as the 95 per cent CI does not cross 0. R2 is .3584 and the model explains 36 per cent of the variation in the dependent variable. This is similar results as 214 Folsom Street.

Regression Temperature With Interaction Between Time and Door

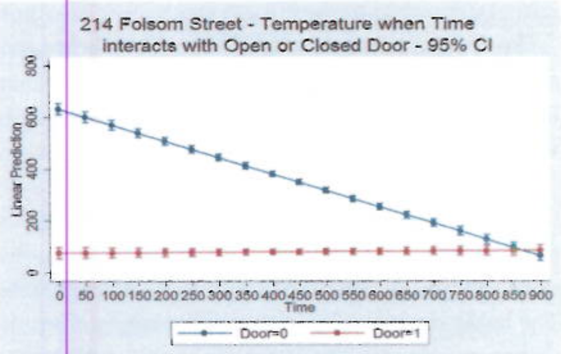
If we interact Time and Door for each model the results are shown in the tables and graphs below:

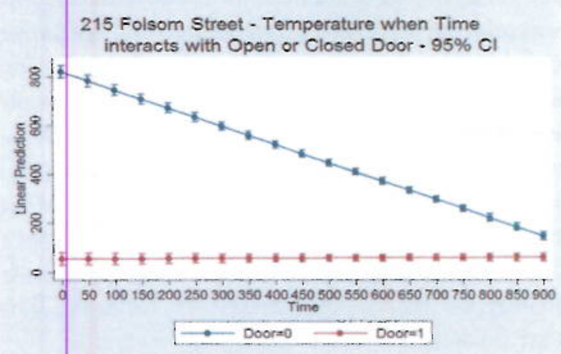
214 Folsom Street	(1)
	Temp_F
VARIABLES	Temp_F
Time_01	-0.628***
	(0.0357)
1.Door	-554.9***
	(23.38)
1.Door#c.Time_01	0.640***
	(0.0357)
Constant	631.8***
	(23.35)
Observations	1,834
R-squared	0.521

Robust standard errors in parentheses
*** p<0.001, ** p<0.001, * p<0.05

215 Folsom Street	(1)
	Temp_F
VARIABLES	Temp_F
Time_01	-0.748***
	(0.0298)
1.Door	-767.0***
	(26.52)
1.Door#c.Time_01	0.757***
	(0.0298)
Constant	821.1***
	(26.52)
Observations	2,482
R-squared	0.524

Robust standard errors in parentheses
*** p<0.001, ** p<0.001, * p<0.05





Very similar results that reveal temperatures reduce over time in the rooms with open doors, but the initial temperatures were high enough that the fire event was not survivable. The rooms with the doors closed remain survivable throughout the fire event.[1]

1 I ran several diagnostic tests on both 214 and 215 Folsom Street Regression Model to determine if the data was in line with the critical assumptions of OLS. Linearity: The data was not linear due to the nature of the data collected. The Normality of Errors: Errors are not perfectly normal, but they are not too far off. Heteroskadasticity: The models have heteroskadastic errors; therefore the regression will need to be run using the robust command. Omitted variables: Stata ovtest shows Ho: model has no omitted variables. Multicollinearity: Multicollinearity is not a problem for the model.

Conclusion

The data reveals that rooms with door open were not survivable until late in the fire event, which was too late for rescue of the victim. Rooms with doors closed remained survivable throughout the fire event. These results call for a change in rescue tactics and public fire education. Victims who cannot find a tenable escape route can retreat to an uninvolved room and close the door and remain there until firefighters can suppress the fire and then effect rescue.

This is a departure from tactics that resulted in immediate rescue attempts which exposes the firefighter and victim to the extreme temperatures and lethal gases. Vent enter search procedures should be altered to vent enter isolate search to instill in the firefighter the need to isolate the search room from the fire by closing the door.

Additionally, public fire education will need to be updated to include the option of retreat and shelter in place. Due to the rapid temperature increase exhibited by the current furniture, it may also be prudent to sleep with bedroom doors closed, decreasing the sleeping residents' risk to extreme temperature and toxic gas exposure prior to discovery of the fire. Dispatch protocols must be developed to include a shelter in place instruction with specific instructions on controlling the door and placing something in the window to notify firefighters of their location. Firefighters will need additional training to modify victim rescue tactics and self-rescue decision making process. Specifically, firefighters must be able to determine when a space is untenable for a victim therefore entry into this space for rescue is futile and should not be attempted.

About the Author:
Fire Chief Blackwell has served in each level of rank up to and including Fire Chief. While a volunteer, Chief Blackwell worked as a career paramedic and police officer. Chief Blackwell's fulltime Fire Service career has included appointments as Fire Chief of a volunteer, combination and career department. Chief Blackwell has also served as an Assistant Chief of a federal nuclear weapons facility. In 2010, Chief Blackwell was appointed Fire Chief of the Spartanburg Fire Department in Spartanburg, South Carolina. Chief Blackwell is currently a PhD student at Oklahoma State University.

References

1. Goodson C and Murnane L. Essentials of Fire Fighting. 5th edition. Stillwater, OK: Fire Protection Publications, 2008.
2. Thompson DL. Firefighter's Handbook, 3rd Edition. Clifton Park, NY: Thompson Delmar Learning, 2009.
3. NFPA. Exit Drills in the Home (E.D.I.T.H.). Quincy, MA: National Fire Protection Association, 2011.