Large Scale Outdoor Fire Demonstration Program

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Greenstone Industries
(now US GreenFiber)

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TABLE OF CONTENTS

Executive Summary

The Large Scale Outdoor Fire Demonstration Program sponsored by Greenstone Industries, Inc. and conducted on June 23, 1998 was a demonstration of the combustion characteristics of buildings employing conventional residential wood frame construction practices. The demonstration illustrated the relative performance of both fiberglass and cellulose insulation in comparison to an otherwise identical non-insulated structure in terms of fire resistance, suitability as fire blocking and general combustibility. The intent of the demonstration was to communicate to builders, designers and the fire safety community with up-to-date information and recent research results using actual complex building assemblies built to full scale. An earlier demonstration with similar objectives, titled the Big Burn, was performed approximately twenty years ago with dramatic results. However, there were several technical shortcomings in the earlier effort that are addressed by this current state-of-the-art demonstration.

The demonstration was performed at the Maryland Fire and Rescue Institute under the supervision of both The Code Consortium, Inc. and Steven Winter Associates and documented by professional color video and photography. The three identical two-story wood structures separated by an equal distance in excess of twenty-eight feet to assure minimal radiative exchange between buildings, were built utilizing prevalent residential construction practices. In each of these buildings, a common size door and window rough opening was provided for access, view of the interior and necessary combustion ventilation. Visual access was provided by means of a wire glass window to view the progressive spread of combustion through the inter-story exterior wall cavity. Wood cribbing was placed at the first floor level and burned to simulate a room contents fire.

Each structure was instrumented with two independent channels of instrumentation and dataloggers to measure temperatures at several locations, including both the interior and exterior of the wall, and roof assemblies. The elapsed time and temperature of the first floor room fire were measured throughout the demonstration and complied well with the requirements of the Uniform Building Code Standard 26-4 and were consistent among the three units.

The results of this demonstration were very dramatic and correspond closely with the results achieved by the National Fire Laboratory of the National Research Council of Canada. The cellulose structure maintained its structural integrity in excess of 24 minutes longer than the fiberglass structure, translating to an increased fire resistance of 57% as compared to the 55% improvement achieved in the laboratory study. The critical mode of failure was the measure of resistance provided by the wall assembly.

1.0 Background

Greenstone Industries, Inc., a subsidiary of the Louisiana-Pacific Corporation contracted with Steven Winter Associates, Inc. and The Code Consortium, Inc. to design and document the results of a larger scale fire demonstration to assess the relative performance of common insulation products in conventional detached residential wood construction. Fire safety issues have long been the subject of debate within the insulation community but recent developments in building science research has prompted renewed interest in how these results apply to full-scale assemblies. An earlier demonstration performed by the Rhode Island Energy Corp. approximately twenty years ago, produced dramatic results. However, technical shortcomings associated with this effort, in both the design of the structures and the method of documentation, required a new effort utilizing both the results of research and established testing protocol, as a basis for comparison.

Recent efforts by the building science community have documented that walls insulated with cellulose insulation serve as continuous fire blocking material while dramatically increasing the fire resistance of the wall assembly. The most comprehensive research performed to date on this issue is the recently completed study by the National Fire Laboratory of the National Research Council of Canada. The ultimate objective of this report was to perform a comprehensive evaluation of common assemblies, utilizing standard methods that could be prescriptively adopted by building codes and trade associations. The study, jointly funded by the Canadian government and trade associations representing the gypsum, fiberglass and cellulose industries concluded the following:

> "The fire resistance performance of an assembly with glass fiber insulation in the wall cavity was slightly lower than that of a non-insulated assembly" and "The installation of cellulose fiber in the wall cavity provided an increase in the fire resistance performance of 22% to 55% compared to a non-insulated assembly."[1]

2.0 Objectives

How this improved fire performance would influence fire development in a complex assembly such as typical residential wood frame construction was unknown. While experimental results performed to standard scientific protocols are fundamental to any comparison, the study of full-scale structures is of value in demonstrating complex unforeseen influences and vulnerabilities of a particular assembly. Conventional wood frame construction practices include numerous elements that could conceivably mitigate the benefits of a more fire resistant insulation product such as two-story framing, wood roof trusses, exterior soffits exposed to fenestration openings, and plastic electrical receptacle box penetrations in the gypsum board finish. This demonstration considered all of these elements and attempted to determine their respective influences. The primary objective of this demonstration was to document whether the results of the earlier experimental data would correspond with a conventional building assembly.

Secondary objectives, corresponding to project tasks, included:

1. Design a wood frame two-story construction assembly typical of current residential practices.
2. Develop a protocol as similar as possible to existing standards for the purpose of this demonstration.
3. Document the results of such a demonstration with both visual and quantitative methods.
4. Prepare a brief report summarizing the results of this demonstration and identify key results.

3.0 Methodologies

3.1 Construction

Steven Winter Associates prepared the construction documentation (Appendix A) for three identical two-story wood frame structures built utilizing prevalent residential construction practices compliant with the Council of American Building Officials (CABO) *One and Two Family Dwelling Code*. The structures were intended to replicate the most common building practices with 2 x 4 at 16" on center (o.c.) Western Platform framing and wood roof trusses at 24" o.c. The interior dimensions of each floor measured 12' by 8' with 8' high ceilings, both ceiling and walls were finished with ½" regular gypsum board, taped and spackled. The exterior was finished with ½" nominal Oriented Strand Board (OSB) sheathing and perforated vinyl soffit with aluminum ridge venting. All panel material was consistently oriented in the same direction with identical seaming and fastened as per the CABO *Fastener Schedule for Structural Members* requirements. In each of the three buildings, a common size door opening and window opening was provided for access, view of the interior and necessary combustion ventilation. Visual observation of the progressive spread of combustion in the exterior wall was provided by means of a wired glass window over the width of a single wall cavity continuing the full height of the structure. The structures were constructed by an independent general contractor under the supervision of Steven Winter Associates for compliance with the Construction Documents and were deemed to be compliant.

The sole distinction between the units, apart from their relative location, was the type or absence of insulation. The wall cavities of Unit A, as designated on the site plan, were insulated with fiberglass batt insulation as manufactured by Certainteed, the full depth of the cavity, an equivalent R-13 value, and the attic floor was insulated with blown-in, loose-fill material to achieve a R-30 value. The wall cavities of Unit B were insulated with spray applied cellulose insulation as manufactured by Greenstone Industries; the full depth of the cavity, or an equivalent R-13 value, and the attic floor was insulated with blown-in, loose-fill material to achieve a R-30 value. Unit C, received no insulation and served as a relative comparison of any additional resistance provided by the insulation material. Professional insulation contractors installed both insulation materials as per manufacturers' recommendations.

The three structures were erected as designated on the site plan at the Maryland Fire and Rescue Institute – Northeast Training Center on the Aberdeen Proving Grounds, Aberdeen, Maryland. The three units were separated by a minimum distance in excess of 28' with the cellulose insulated unit located between the other two units, and therefore potentially subject to the greatest amount of radiant exchange (exposure to heat). The framing and sheathing of the three units was completed the week of May 25, 1998. Cellulose insulation was installed June 3rd and all buildings were loosely tarped so as to prevent the entry of rain. The units were provided a two-week period so the materials could acclimate with the surrounding environment at which time the gypsum board finish and the fiberglass insulation was installed by an independent contractor. Another week was provided to assure acclimation of the completed structures.

3.2 Protocol

For the purpose of this demonstration, having no applicable standard, we chose to adapt the Uniform Building Code Standard 26-4 (1994) used for the purpose of full-scale multi-story buildings where the "primary performance characteristics to be evaluated" include "capability of the test panels to resist vertical spread of flame within the core of the panel from one story to the next" and "capability to resist lateral spread of flame from the compartment of fire origin to adjacent spaces." The specified instrumentation, documentation methods, and test procedure were closely approximated and serve as the basis for comparison.

3.3 Instrumentation

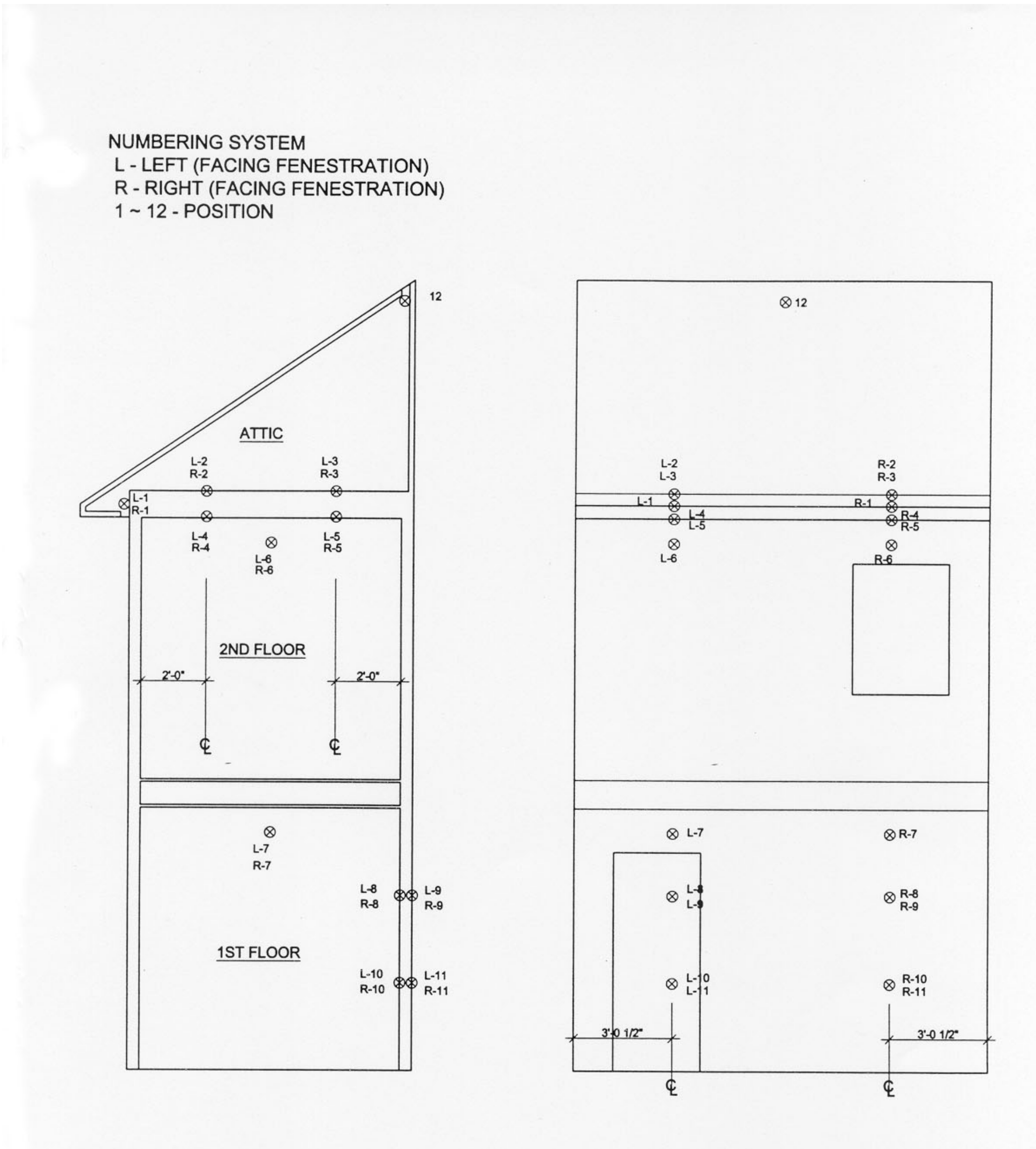
A total of (66) 20 Gauge Type K thermocouples and high temperature resistant wiring were used to document the specific temperatures of both lateral and interstitial points throughout two sections of each unit and as indicated on diagram Figure 3A.

Moisture readings were taken at three points of each unit with a non-destructive digital moisture meter (Tramex Wood Moisture Encounter) to the depth of approximately 1" at the corners to determine if the adjacent framing had absorbed any moisture present in the "wet spray" application of cellulose or the environment at large. The meter was adjustable for specific gravity of the wood species employed and the ambient air temperature. These measurements were taken twice at the time of drywall installation and a day prior to the demonstration.

3.4 Data Collection

Each unit was instrumented with two independent channels, designated as left and right, whose data was collected by two independent data acquisition devices (Campbell Scientific CR10X). Thermocouple locations may be generally categorized as wall, floor and air. Wall thermocouples were placed as pairs at the 2'-8" and 5'-4" heights centered between the width of the exterior wall cavity. Each pair was divided; one thermocouple placed adjacent to the gypsum board and one placed adjacent to the OSB sheathing. This configuration occurs at a total of four points within a single elevation at the exterior wall cavities. A plastic electrical receptacle was installed at 1'-6" height within the same cavity. The intent of the wall thermocouples was to identify the rate of fire spread both vertically through the wall cavity and laterally through the wall assembly between adjacent spaces. Air temperatures within each structure are measured 6" from the ceiling on both the right and left channel at both the first and second stories. Air temperatures in the attic space were measured at both the right and left side of the soffit and at a single location 6" below the center of the ridge vent. Air temperatures provided a quantitative measurement of the rate of fire spread/growth for not only the wood crib designed to approximate the furnace temperatures prescribed in the UBC Standard 7-1 (1994) but also the level of involvement at each story. The floor of the attic was instrumented at both the top and bottom side of the 2 x 4 bottom chord of the roof truss. The floor temperatures provide an indication if the direction of fire spread is from below or above and/or from left or right.

Figure 3A: Thermocouple Diagram



3.5 Video and Photographic Documentation
An independent contractor with two cameras, one stationary and one roaming performed video documentation. The stationary camera, elevated on the "basket" extended from the end of an aerial ladder on a fire department truck, captured all three structures with an aerial view and provided a continuous time record of the first 60 minutes of the fire demonstration, at which time the tape was changed and documentation resumed. This change, as reflected in Table 4A, created a lapse in documentation of less than 30 seconds. The roaming cameras were hand-held

and provided for "up close" documentation of specific elements such as the fire development of the wood crib, fire growth in the wall cavity and ignition procedures. In addition to the video documentation, 35mm photographic images were taken of construction process and at the time of the demonstration. Witnesses also documented this demonstration having been performed in the presence of a public audience.

4.0 Results

4.1 Video Documentation

The structures were ignited on June 23, 1998 at 10:47:00 AM. Humidity and wind speed did not exceed the prescribed limits of the UBC Standard 26-4 protocol at any time during the demonstration. The "Visual Observations from Stationary Video Documentation" time log provides a brief synopsis of those events visible from the stationary video camera, a distance of approximately 100' and commentary made by Rick Thornberry (RT) of The Code Consortium, Inc. during the demonstration. The nature of these events is progressive and therefore times associated with a particular event are merely approximations. The log of visual observations has, however, been correlated with the collected data and is believed to demonstrate very good correspondence. The start time is identified by the camera and the time identified by the commentator differ by approximately 1 minute, contributing factors to this delay being the time required to start ignition and the official time record being relayed to the commentator verbally.

Table 4A Visual Observations from Stationary Video Documentation

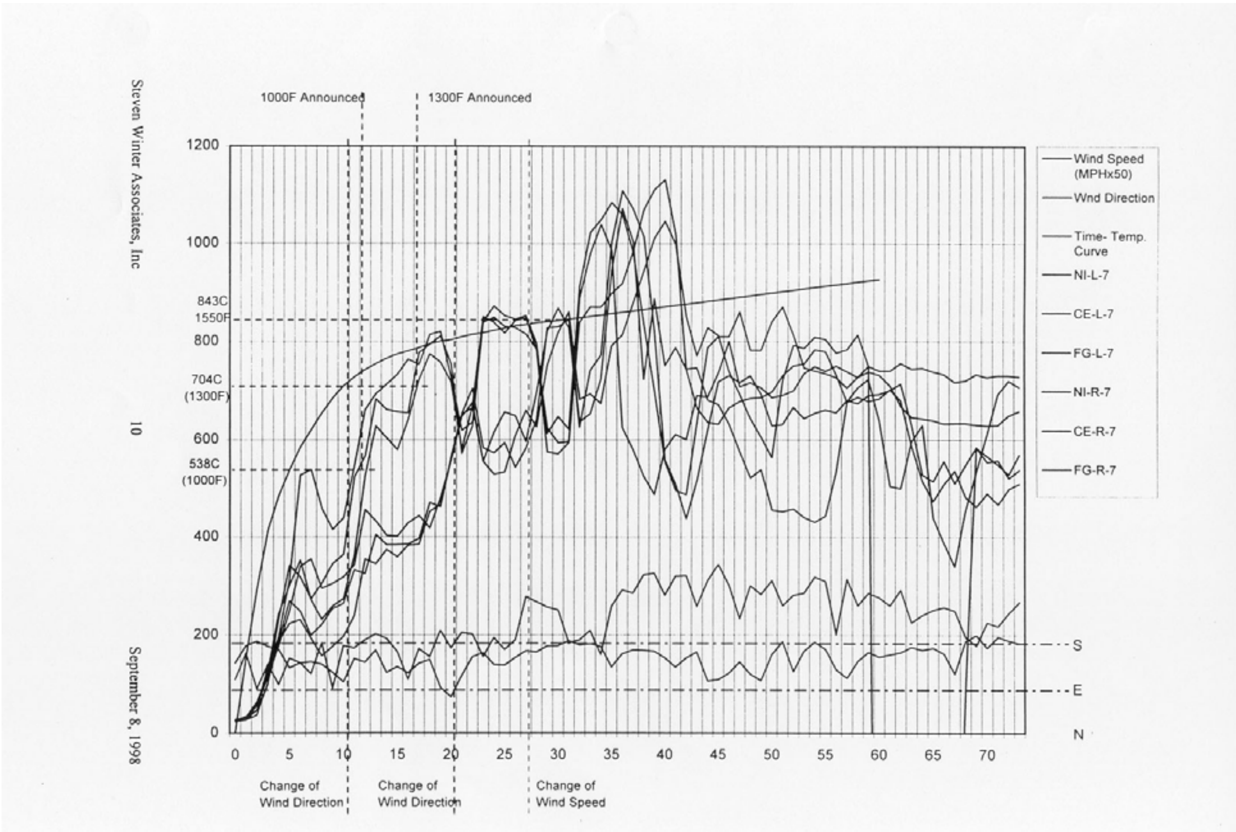
Time	Elapsed Time	Observation
10:48:00 am	00:00	Ignition of cribs
	01:30	Smoke visible from all units
	11:54	1000°F temperature announcement, 1st story interior air
	13:00	Exterior sheathing of non-insulated unit burning
	14:17	15 minute announcement
	15:20	Non-insulated ceiling drywall collapse
	18:00	Rough door framing of non-insulated unit burning
	18:52	RT announces all three cribs are fully involved in fire
	19:12	20 minute announcement
	20:00	Fiberglass unit first story ceiling has collapsed
	20:55	RT holds hand to cellulose window cavity
	21:00	Smoke visible from window openings of both fiberglass and non-insulated units
	23:00	Ceiling of cellulose unit still visible
	23:45	1300°F temperature announcement, 1st story interior air
	24:30	Ceiling of first story cellulose unit collapses
	26:52	1500°F temperature announcement, 1st story interior air
	28:00	Soffit of fiberglass unit burning
	29:10	30 min. announcement
	30:00	Heavy smoke visible from fiberglass unit ridge vent and flames visible thru the attic window

32:00	Attic air temperature of fiberglass unit announced as 800°F
32:20	Attic air temperature of cellulose announced as 200°F
32:40	Attic temperature of non-insulated unit announced as 1000°F
34:00	SWA abandons real time display of data
36:00	Soffit of cellulose unit burning
39:40	Attic trusses at non-insulated unit collapse
40:05	Attic trusses at fiberglass unit collapse
40:10	Collapse of non-insulated unit
42:26	Collapse of fiberglass unit, RT announces elapsed time of 43:20
60:00	Tape changed, 21 second lapse
66:45	**Collapse of cellulose unit, RT announces elapsed time of 68:08.**

4.2 Air Temperature Data Graph

The wood cribbs had been designed to simulate a residential light load room content fire of approximately 5 lb./sf. Southern Pine Fir members were assembled as per the requirements of UBC Standard 26-4 in the configuration as detailed by the construction documents. This crib produced temperatures that approximated the time-temperature curve prescribed by the UBC standard 7-1, at the 5, 10 and 30 minute marks. The temperature rise as measured by thermocouples R-7 and L-7 essentially reaches each mark within a minute of the designated requirement. The attached "First Story Air Temperature Graph," Figure 4B illustrates the variation of the temperatures from the ideal time-temperature curve as well as from each other within the same unit. The influence of both wind speed and direction are also identified on the graph. The maximum acceptable wind speed of 10 mph was never exceeded during the demonstration. These influences are reflected as dramatic momentary changes in temperatures uniformly affecting all units. Both the left and right channels are identified in this graph and form in essence two distinct groupings affected by the proximity to the wood crib, which is asymmetrically located within the space. Each grouping of channels closely approximates each other and demonstrates the uniform development of all wood cribs at essentially the same time.

Figure 4B: 1st Floor Air Temperature



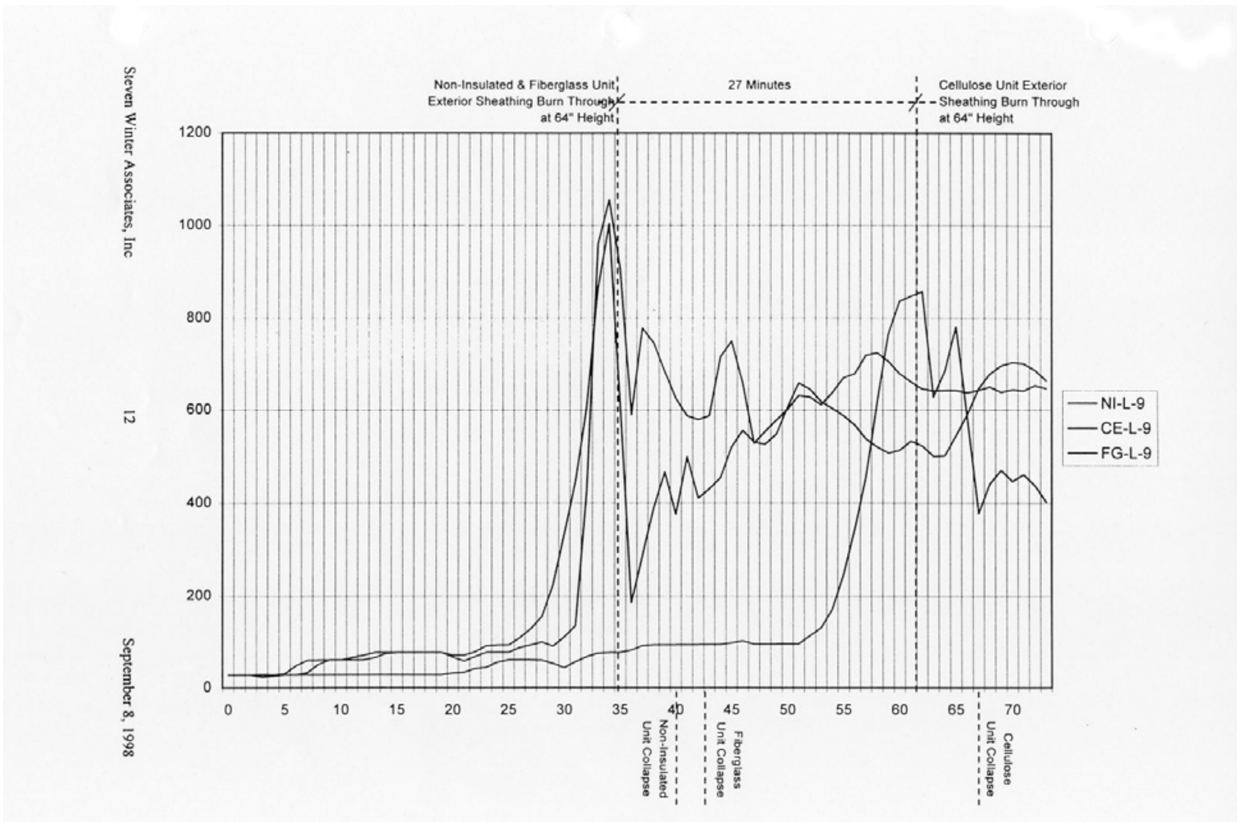
4.3 Thermocouple Data Analysis

The thermocouple data have been assembled in three primary divisions; all left channel points for each individual unit, the same left channel point for all units, and a comparison of the left and right channel at the same point.

All thermocouple data for the left channel of each unit have been plotted on the same graph for the purpose of documenting the correspondence and progression of temperatures through the structure. On each graph, visual observations such as the collapse of the first floor ceiling, roof trusses and the unit itself are noted if applicable. At the time of the collapse, all data points rapidly merge towards a mean temperature as the thermocouples then rest in a single mass. Of interest, apart from identifying the specific time of collapse, is the progression of fire both vertically and laterally through the structure. The tighter the grouping of lines, the less resistance provided by the assembly to the spread of fire.

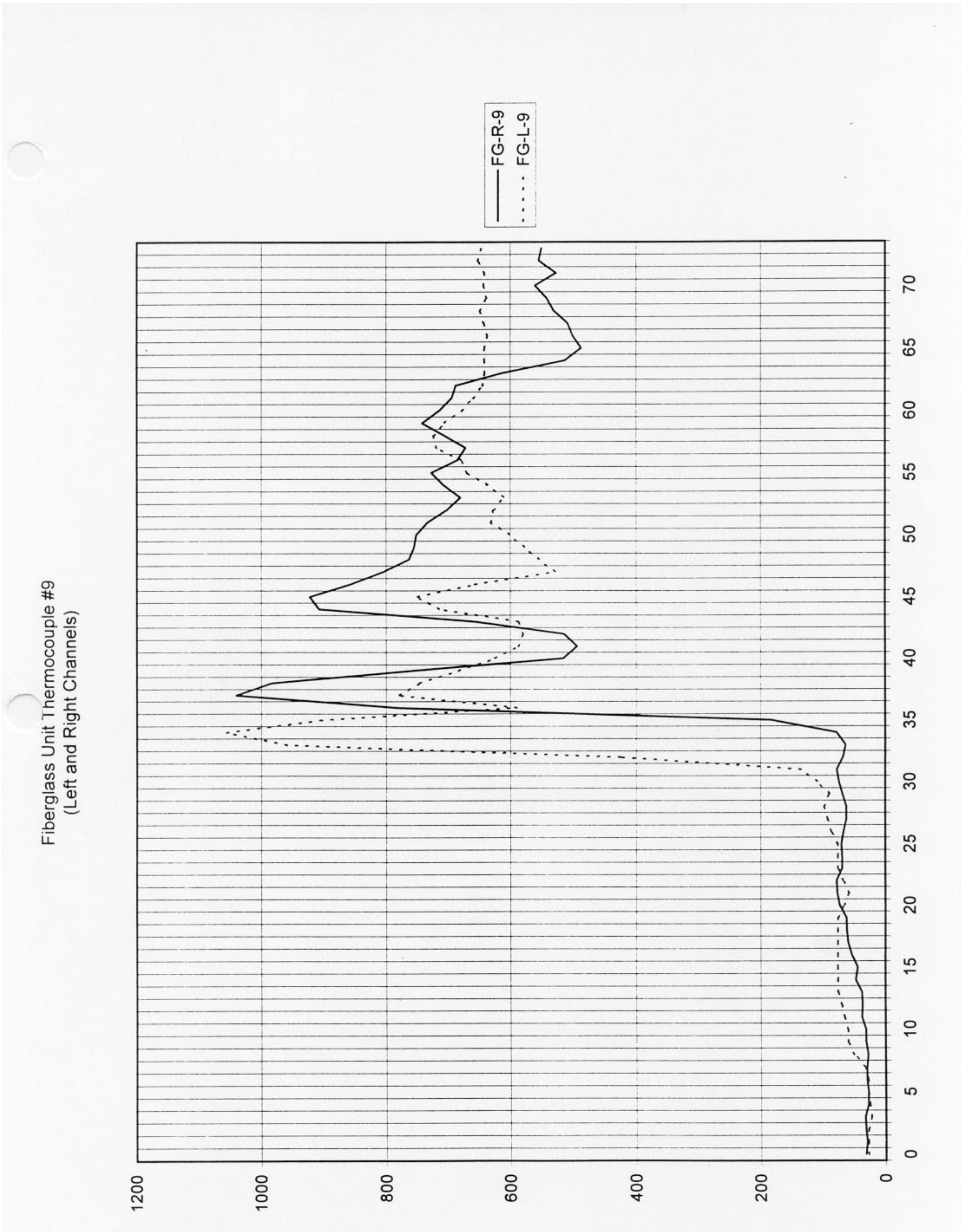
The same point at each unit is graphed so a comparison can be made as to the progression of fire, both vertically and laterally. Visual observations from the video log are identified on the graphs where appropriate. Interpretation of the graphs may be made by identifying the time difference between units for the temperature to rise to a level supporting combustion. An example of such an interpretation would be the resistance demonstrated by thermocouple location L-9, Figure 4C, the interior surface of the OSB sheathing. The non-insulated and fiberglass unit temperatures rose to 800□C at the 35th minute; however, the cellulose unit provided 27 minutes additional resistance before reaching the same point. At both points, the OSB continued to burn for approximately three minutes, and five minutes later the collapse of the structure occurred.

Figure 4C: Temperature at L-9



Finally, both left and right channels at each point were examined for correspondence with each other. Thermocouples at the right channel of the non-insulated unit were not used at locates R1-6 and the thermocouple at point L-11 at the fiberglass unit failed. This analysis, as exemplified by Figure 4D, demonstrates very good correspondence between left and right channels with a slight time lag of approximately 2-3 minutes due to the asymmetrical placement of the crib. This redundancy of data provides a high measure of confidence in the comparison of a single data channel.

Figure 4D: Left and Right Channel Correspondence



4.4 Moisture Measurements

Three moisture measurements were taken at the west corner of each unit at 2' height increments, see Table 4A. The specific gravity of this composite assembly, composed of Spruce Pine Fir framing and OSB sheathing, was assumed to be .40 for the purpose of comparison. This assumption, although not precise, provides a relative measure of the respective units to a margin of error within 1%. The three-week period provided for the material moisture levels to normalize with its surrounding environment is believed to have dissipated any moisture introduced during the cellulose application process. The slightly elevated moisture levels measured in the cellulose unit are perhaps attributable to the hygroscopic properties of this insulation material and would otherwise be present in the material under ordinary circumstances.

Table 4A Moisture Measurements

UNIT	2' HEIGHT	4' HEIGHT	6' HEIGHT	**AVERAGE**
Non-Insulated				
6/15/98	18%	16%	18%	**17%**
6/22/98	16%	14%	15%	**15%**
Fiberglass				
6/15/98	15%	15%	15%	**15%**
6/22/98	19%	15%	14%	**16%**
Cellulose				
6/15/98	18%	21%	16%	**18%**
6/22/98	17%	20%	16%	**18%**

5.0 Conclusions

Data collection from this comparative demonstration clearly and dramatically demonstrates the improved fire resistance provided by cellulose insulation relative to fiberglass batt insulation or no insulation at all. Specific conclusions derived from this demonstration are as follows:

1. The cellulose unit collapsed 24:32 minutes after the collapse of the fiberglass unit. This represents an increased resistance in excess of 57% that corresponds well to the best results from laboratory test results of 55%.
2. The collapse of all three buildings occurs within 8 minutes of thermocouple location L-9 reaching 800°C. The cellulose structure provided an additional 27 minutes of lateral fire spread resistance. This lateral resistance proved to be the critical path precipitating collapse.
3. The maximum air temperature (approximately 1200°C) of the second story space for both the fiberglass and cellulose insulated units occurred within four minutes of each other, demonstrating where insulation is not present in the floor assembly, the progression of fire through the floor assembly is very similar among the units.

6.0 References

1. National Research Council Canada, *Results of Fire Resistance Tests on Small-Scale, Insulated and Non-Insulated, Gypsum Board Protected Wall Assemblies*, Client Report A-4057.2, July 13, 1994.
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