Design Options Analysis on a Heat Wrap used on PVC Pipe Connections in Cold Weather Conditions

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Cold weather conditions produce challenges for plumbers making PVC joint connections, because lower temperatures increase the initial set time required for plumbing solvents to cure during the PVC connection process. A heat wrap has been developed that reduced set times for PVC connections in cold temperatures. The purpose of the current research is to determine if the design can be improved to increase the performance of the heat wrap. Testing was performed on three heat wrap design materials: open mesh, neoprene, and Gore-tex. The results of testing determined that Gore-tex was the most effective heat wrap material for increasing the temperature of the PVC pipe joint, thus, reducing set times of PVC connections.

Key Words: polyvinyl chloride (PVC), solvent, cold temperatures, heat wrap

Introduction

Cold weather conditions challenge the construction process by creating problems for plumbers joining polyvinyl chloride (PVC) and chlorinated polyvinyl chloride (CPVC) piping. The main impact of cold temperatures on PVC pipe connections is that lower temperatures increase the pipe joint's "initial set" time. Initial set time is defined as the amount of time the pipe adhesive solvent needs to cure, thus, making the pipe joint stable enough for additional joints to be made without compromising the integrity of the previously completed joint (*Cold Weather-Arrow*, 2007).

Warming the pipe joint decreases the initial set time, and study of the heat wrap conducted by Smith and Williams in 2006, showed that the open mesh heat wrap did raise the temperature of the pipe. The heat wrap consisted of a strip of open mesh fabric with pockets sewn in. In each pocket, a heat pack was inserted to produce heat, and the strip of fabric was wrapped around a pipe and held in place with Velcro (Smith and Williams, 2007).

The question at the end of the 2006 study was whether the open mesh fabric was the most effective material to use on the heat wrap. The current study tests the open mesh and two other materials to find which material is most effective. Criteria for the most effective design material was based on which raised the temperature of the pipe the quickest, reached the highest temperature, and sustained a high temperature for an extended amount of time. Materials tested included the original open mesh fabric, neoprene, and Gore-tex. Results from these tests would define which of the three materials was the most productive and efficient in raising the temperature of the pipe, thus, decreasing the initial set time of the PVC connection.

Background

A PVC pipe connection consists of a hub-and-spigot connection for two pipes or fittings. The two sections of PVC are bonded together with an adhesive, welding solvent. A four step process is recommended when joining PVC connections. First, the joining surfaces of PVC pipe must be softened and made semi-fluid by primer. Secondly, sufficient solvent must be applied to fill gaps between pipe and fitting. Third, assembly of pipe and fittings must be made while the surfaces are still wet and solvent is still fluid. Fourth, joint strength develops as the solvent cures (*CPVC*, 2007).

According to the *Basic Guidelines for Connecting PVC Pipes 2005*, cold temperatures cause solvents to penetrate and soften PVC pipe surfaces more slowly than in warm weather conditions. Due to cold temperatures, longer cure times are recommended before addition PVC connections are performed. Longer cure times are necessary because the solvents evaporate much slower in cold temperatures. For example, the cure time for a PVC connection at 10 to 20°F is 8 times longer than at 60 to 100°F" (*Cold Weather-Arrow*, 2007). "Primers and cements do not penetrate and soften PVC pipe as quickly in cold weather (below freezing) as in warm weather. It will take longer for the solvents to evaporate in cold temperatures so allow for a longer than normal cure time" (*Installation Guide*). Table 1 below represents the setting times for 2 inch PVC pipe at temperatures from 0 to 80 degrees Fahrenheit, in intervals of 10 degrees Fahrenheit. The chart of set times shows that at higher temperatures require shorter setting times.

Table 1 – Setting Time for 2 Inch Pipe (*Cold Weather-Arrow*, 2007).

Temperature	Setting Time
0 Degrees F	17 Minutes
10 Degrees F	14 Minutes
20 Degrees F	12 Minutes
30 Degrees F	10 Minutes
40 Degrees F	8 Minutes
50 Degrees F	7 Minutes
60 Degrees F	6 Minutes
70 Degrees F	4 Minutes
80 Degrees F	3 Minutes

Existing measures used to heat PVC pipe connections include industrial hair dryers and propane torches. Both processes will heat unevenly, and more importantly, the temperature can exceed the maximum temperature allowed before the PVC begins to degrade and loose strength.

The heat-wrap was developed to provide even heating to a controlled maximum. The design for the heat wrap consisted of two layers of material sewn together in a 6 inch by 32 inch rectangular wrap. Pocket dividers are sewn into the wrap every three inches to hold two heat packs in each section. Velcro strips are used to secure the heat wrap around the pipe and pipe connection. The results of testing showed that the temperature of the pipe was raised to predictable level which would shortened the curing time of the PVC solvent, and stayed at that temperature for a time sufficient to reach "initial set" (Smith and Williams 2006).

HotHands-2 was the type of heating packs used to as the heat source. HotHands-2 produces heat when chemicals inside the pack are mixed together and exposed to air. HotHands-2 heating packs are made of a mixture of iron powder, water, salt, activated charcoal, and vermiculite (*HotHands-2,* 2007). Chemicals are enclosed in a porous paper pack that is sealed in individual air-tight packages. The user must remove the heat packs from the air tight packaging and allow 15 to 30 minutes for the chemical reaction to produce heat. Once the heat packs become warm, the HotHands-2 will keep producing heat up to 10 hours. Average temperature of HotHands-2 ranges from 126 degrees F to 144 degrees F. If heat decreases during usage, user should expose HotHands-2 to air and shake contents to repeat thermal reaction (*HotHands-2*, 2007).

One advantage of using the HotHands2 heating packs is that they produce heat up to a maximum 144 degrees Fahrenheit. ASTM standards for heat tolerances for PVC schedule 40, grade 1 pipe includes heat deflection at 160 degrees Fahrenheit. The heat tolerance is recommended by ASTM to ensure that the integrity of the pipe is not compromised. Therefore, the use of the HotHands-2 heating packs would be safe to use on any PVC plumbing connection (CPVC Schedule Fittings, 2007).

The purpose of the current study was to explore different materials that could be used in the heat wrap to increase the efficiency. The original study used an open mesh fabric because the heat packs required oxygen to start the chemical reaction (*Open-Mesh Fabric: Detailed Product Description*, 2007). During the 2006 study, it was found that the heat packs continued to function for an extended period of time when covered (Smith and Williams, 2007). One of the conclusions of the test was that a less open fabric might hold in more of the heat, and could prove to be more effective. The current study chose two additional fabrics to test: neoprene and Gore-tex. Along with air permeability requirements, the heat wrap design included characteristics of durability, water-resistance, and temperature resistance. Neoprene has medium air permeability and additional properties of "resisting degradation from sun, ozone and weather; chemical and temperature resistance; durability; high burning resistance; and has outstanding resistance to damage caused by flexing and twisting" (*Neoprene*, 2007). The insulated gore-tex has low air permeability and supplementary properties of being "durably waterproof, extremely cold resistant, tremendously crease resistant, and especially long-lasting" (*Gore-Tex*, 2007).

Methodology

The testing was based on simulating extreme cold weather conditions and measuring the temperature of the pipe while using the three different types of heat-wraps. The most effective design material would raise the temperature of the pipe the quickest, reach the highest temperature, and sustain a high temperature for an extended period of time. These three criteria factors combined to create a temperature curve.

Three heat wraps, one made of each of the three different materials, was placed inside a freezer at a controlled temperature of 0 degrees Fahrenheit. Six tests were performed on each heat wrap, for a total of 18 tests, measuring the temperature of the pipe. Temperature readings were taken at one minute time intervals, and recorded using Dickson SK 500 Data Loggers.

Two-inch PVC was chosen for the testing. The two-inch pipe allowed enough room to install the data loggers and had a shorter initial set time than the larger pipes. The shorter set time allowed more tests to be run in a shorter period of time.

Data loggers are sensors that record the temperature at preset time intervals. During temperature testing, data loggers were placed in two locations. The first location was on the outside of the 2-inch PVC coupling and the second data logger was placed on the inside of the 2-inch PVC pipe. The first location, on outside of the 2-inch PVC coupling, was referred to as the Outside Temperature and the second location, on the inside of the 2-inch PVC pipe, was referred to as the Inside Temperature. The area of the pipe where the temperature is important is where the two surfaces join. Since data loggers cannot be placed in such a small area, the temperature on the outside and inside of the pipe was taken, and the temperature at the joined surfaces was extrapolated. A third data logger recorded the ambient temperature in the test area. The following is the testing procedure:

1. Pipe (2-inch PVC), fitting (2-inch PVC coupling), and data loggers were placed in a freezer for 75 minutes to bring pipe temperatures down to the freezer (ambient) temperature of 0 degrees Fahrenheit. 75 minutes was chosen for cool down period because preliminary freezer tests show that 70 minutes was required to bring 2-inch PVC connection down to 0 degrees Fahrenheit from room temperature of 70 degrees Fahrenheit.
2. Six HotHands-2 heating packs were removed from air-tight packaging and allowed 15 minutes for heating process to occur. HotHands-2 heating packs' directions suggest 15 to 20 minutes for heating process to take place. Six HotHands-2 heating packs were used because that was amount of heating packs that was required to fill the heat wrap sections used during the 2-inch PVC connection tests. If a different size pipe was being tested, then different amounts of HotHands-2 heating packs may be used.
3. HotHands-2 heating packs were placed in heat wrap, two in each of the three heat wrap sections, and heat wrap was applied to joined pipe area and placed in freezer.
4. After 45 minutes the heat wrap was removed. 45 minutes provides sufficient time for all temperature results to be viewed and recorded.
5. 15 minutes was allowed for heating packs in heat wrap to reheat. Per HotHands-2 heating directions.
6. After 15 minute reheating process, heat wrap was placed on pipe. Steps 4, 5, and 6 were repeated until 6 tests were completed on each design material.
7. Loggers were removed after 6 tests were completed and the temperature data downloaded to record temperature results.
8. The data from the loggers was transferred to EXCEL data sheets for analysis.

Test Results

Figure 1 is a test performed on the open-mesh material, portraying outside, inside, and ambient temperature readings for the open mesh design material. The outside temperature reading recorded the temperature between the heat wrap and the outside of the pipe. The inside temperature readings recorded temperatures on the inside of the PVC connection. The ambient temperature reading recorded temperature of the inside of the freezer during temperature testing. The outside logger is directly under the heat-wrap and would have the highest temperatures. The inside logger is recording the temperature on the inside of the pipe, so the temperature of the joining surfaces would be between the inside and outside.

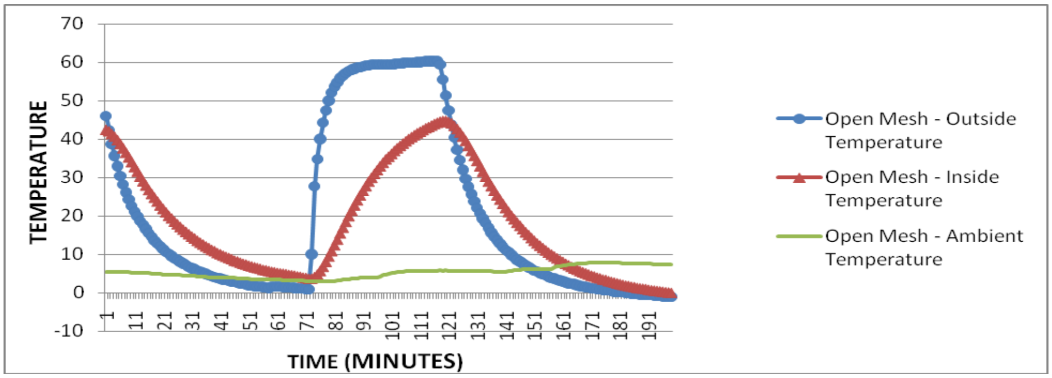

Figure 1: Open Mesh Temperature Curve Example

The temperature test consisted of temperature readings taken at one minute intervals for the outside, inside, and ambient temperature curves. The test began by the PVC connection being placed in the freezer at minute zero. The PVC connection dropped temperature until the outside temperature reached 0 degrees Fahrenheit and the inside temperature reached 3.7 degrees Fahrenheit at minute 75. The inside temperature had less direct exposure to freezer temperatures because it was recorded inside the PVC pipe. At minute 75, the heat wrap was placed on the PVC connection. The heat wrap increases the outside and inside temperature until the heat wrap is removed from the PVC connection at minute 120. The outside temperature reached a temperature of 60.2 degrees Fahrenheit and the inside temperature reached 44 degrees Fahrenheit. At minute 120, the heat wrap was removed from the PVC connection and the outside and inside temperatures decreased due to exposure to freezing temperatures of the freezer. At minute 195, the first temperature was completed and the outside temperature was -0.9 degrees Fahrenheit and the inside temperature was 0.4 degrees Fahrenheit.

The third line represents the ambient temperature in the freezer during the first Open Mesh temperature test. The ambient temperature fluctuated from 3.0 degrees Fahrenheit to 7.1 degrees Fahrenheit. Fluctuations in ambient temperature were due to opening of the freezer door, room temperature PVC connection being placed in freezer, freezer cooling mechanism turning on and off, and the heat wrap generating heat during temperature testing. The fact that the outside logger registered lower than the ambient air at one point may have been due to the calibration of the loggers or their position in the freezer, but the difference did not appear to impact the overall results of the test.

Open Mesh

Figure 2 portrays the outside six temperature curves recorded by the data logger located on the outside of the 2-inch PVC pipe for the Open Mesh design material. Each temperature curve is a result of 45 temperature readings taken at one minute intervals. The systematic procedure for conducting tests was explained in the previous methodology section. The highest recorded temperature curve recorded was Test 6 and the lowest recorded temperature curve was Test 2.

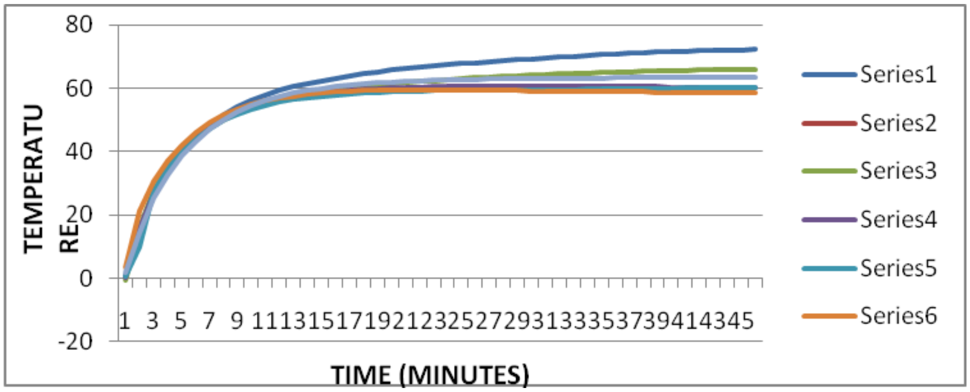

Figure 2: Open Mesh – Outside Temperature Tests

Figure 3 portrays the six inside temperature curves recorded by the data logger located on the inside of the 2-inch PVC pipe for the Open Mesh design material. Each temperature curve is a result of 45 temperature readings taken at one minute intervals. The highest recorded temperature curve was the Test 5 and the lowest recorded temperature curve was Test 1.

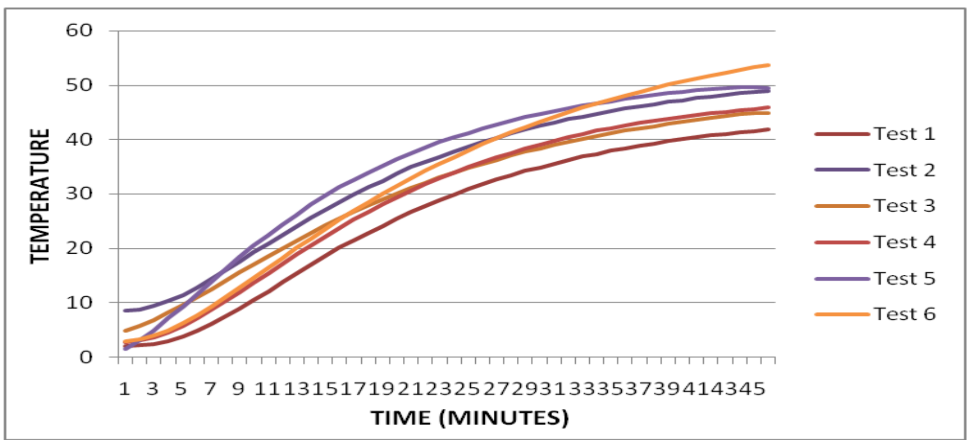

Figure 3: Open Mesh – Inside Temperature Tests

Figure 4 shows the outside average, inside average, and average temperature curves for the Open Mesh design material. The Open Mesh outside temperature curve was composed of 45 sets of temperature readings, each set having 6 temperature readings, averaged in an Excel spreadsheet. After all 45 data sets were averaged, the resulting 45 temperature averages created the Open Mesh outside temperature curve. The above Figure shows that the outside temperature of the PVC pipe reached 50 degrees Fahrenheit after 8 minutes and remains above 50 degrees Fahrenheit for the remainder of the 45 minutes. The last recorded temperature at 45 minutes was 63 degrees Fahrenheit.

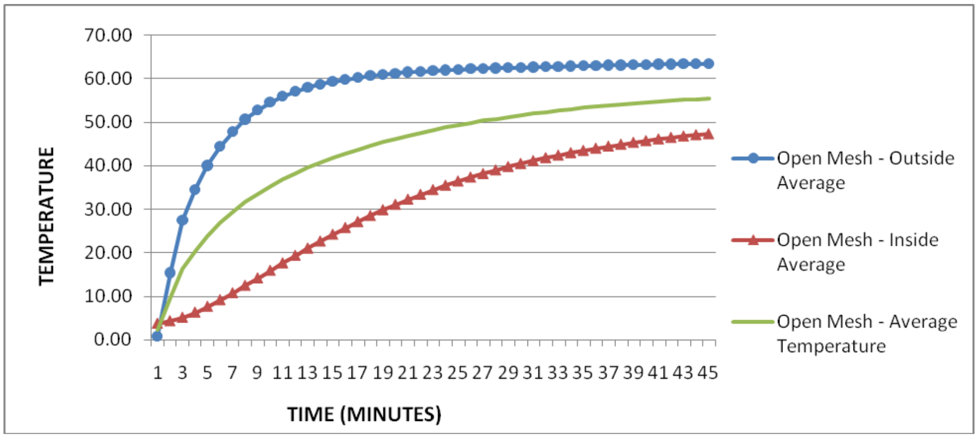

Figure 4: Open Mesh – Inside, Outside, and Average Temperature Curves

Open Mesh inside temperature curve was produced using the same averaging system as the Open Mesh outside temperature curve. The average temperature curve was calculated by averaging all 45 sets of temperature readings in an Excel spreadsheet. After all 45 data sets were averaged, the resultant 45 temperature averages created the Open Mesh outside temperature curve. The Open Mesh average temperature curve shows that the inside temperature of the PVC pipe reached 12.5 degrees Fahrenheit after 8 minutes and reached 40 degrees Fahrenheit after 30 minutes. The last recorded temperature at 45 minutes was 47 degrees Fahrenheit.

The Open Mesh average temperature curve is the average of the Open Mesh outside and inside temperature curves. The average temperature curve also represents the temperature at the joint solvent location of the pipe. The actual temperature in the pipe joint may be slightly higher or lower than the average temperature curve represents. Using the average temperature curve, composed of 45 temperature points, of the pipe joint was sufficient for the purpose of comparing the three heat wrap design materials to determine the most effective design material. Actual temperatures may be required if further research aims to develop a PVC joint set time chart that determines the amount of set time required for specific temperature conditions. Results of the Open Mesh average temperature curve include temperatures reaching 38.3 degrees Fahrenheit after 12 minutes and 50.3 degrees Fahrenheit after 27 minutes.

Neoprene

Figure 5 shows the outside average, inside average, and average temperature curves for the Neoprene design material. All three average temperature curves were calculated in a same manner as the Open Mesh average temperature curves. The above Figure shows that the outside temperature of the PVC pipe reached 50 degrees Fahrenheit after 9 minutes and remains above 50 degrees Fahrenheit for the remainder of the 45 minutes. The last recorded temperature at 45 minutes was 50 degrees Fahrenheit.

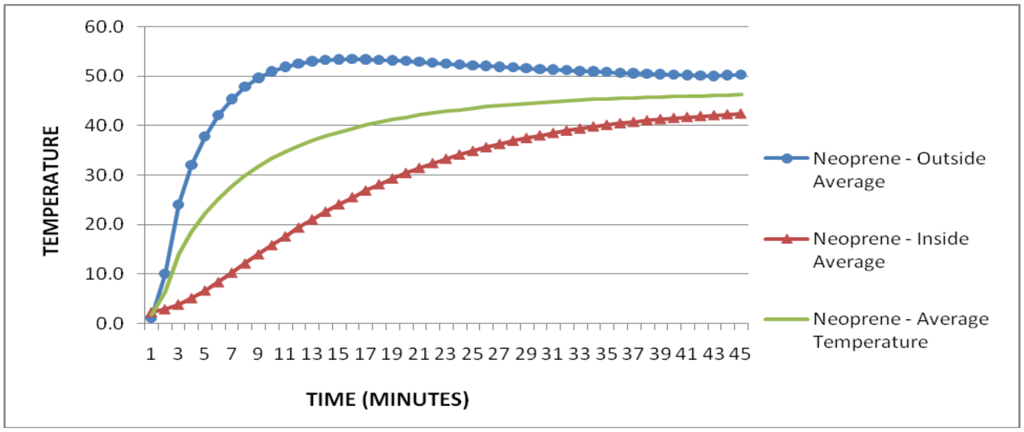

Figure 5: Neoprene – Outside, Inside, & Average Temperature Curves

The Neoprene inside average temperature curve shows that the inside temperature of the PVC pipe reached 12.2 degrees Fahrenheit after 8 minutes and reached 38 degrees Fahrenheit after 30 minutes. The last recorded temperature at 45 minutes was 42.4 degrees Fahrenheit.

The Neoprene average temperature curve is the average of the Neoprene outside and inside temperature curves. The average temperature curve also represents the temperature at the joint solvent location of the pipe. Results of the Neoprene average temperature curve include temperatures reaching 35.9 degrees Fahrenheit after 12 minutes and 44.1 degrees Fahrenheit after 27 minutes.

Insulated Gore-tex

Figure 6 shows the outside average, inside average, and average temperature curves for the Insulated Gore-tex design material. All three average temperature curves were calculated in the same manner as the Open Mesh and Neoprene average temperature curves. The above Figure shows that the outside temperature of the PVC pipe reached 56.2 degrees Fahrenheit after 8 minutes and remains above 50 degrees Fahrenheit for the remainder of the 45 minutes. The last recorded temperature at 45 minutes was 86.8 degrees Fahrenheit.

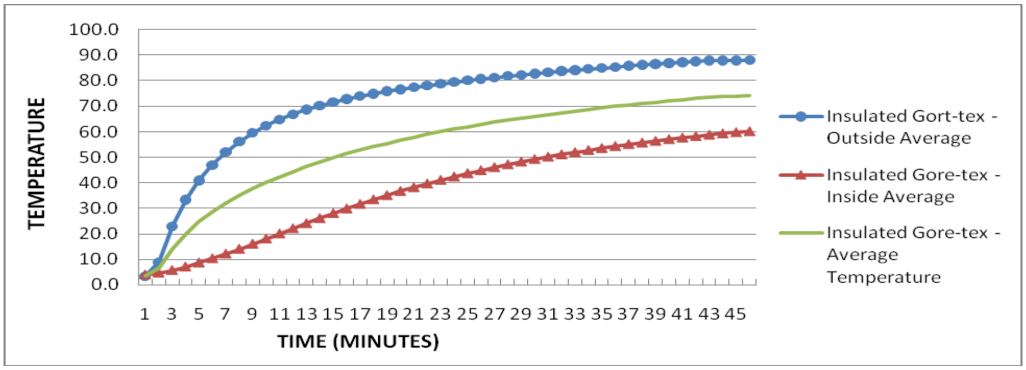

Figure 6: Gore-tex Outside, Inside, and Average Temperature Curve

The Insulated Gore-tex inside average temperature curve shows that the inside temperature of the PVC pipe reached 14.1 degrees Fahrenheit after 8 minutes and reached 49.3 degrees Fahrenheit after 30 minutes. The last recorded temperature at 45 minutes was 58.7 degrees Fahrenheit.

The Insulated Gore-tex average temperature curve is the average of the Open Mesh outside and inside temperature curves. The average temperature curve also represents the temperature at the joint solvent location of the pipe. Results of the Insulated Gore-tex average temperature curve include temperatures reaching 44.6 degrees Fahrenheit after 12 minutes and 63.7 degrees Fahrenheit after 27 minutes.

Comparison of the Three Designs

The comparison of the data shows that the Gore-tex is the most effective material for the heat wrap. The three design criteria for the most effective heat wrap includes the heat wrap design material that raises the temperature of the pipe the quickest, reaches the highest temperature, and sustains a high temperature for an extended period of time.

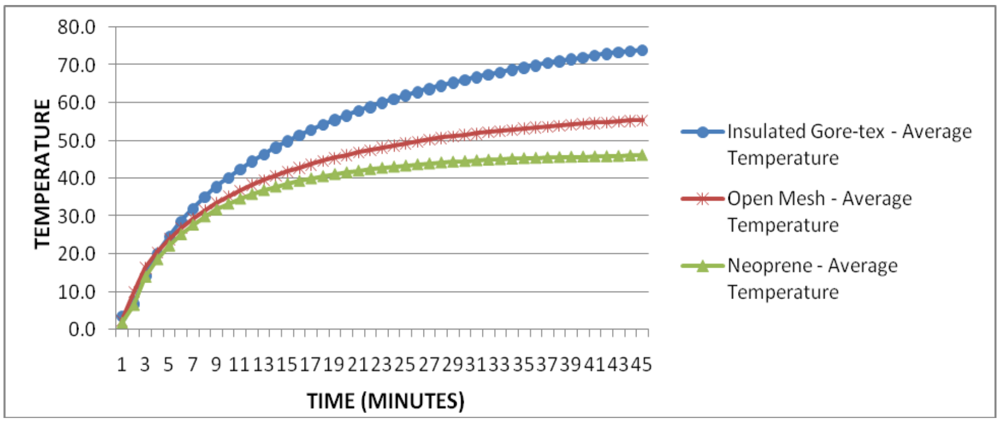

Figure 7: Comparison of the Three Heat Wrap Designs

Conclusion

The purpose of this research was to determine which of the three heat wrap design materials would be the most effective in raising the temperature of the PVC pipe connection. Results from temperature tests of the three heat wrap design materials of Open Mesh, Neoprene, and Insulated Gore-tex, produced average temperature curves for each design material. The three average temperature curves were evaluated and compared to determine the most effective heat wrap design material. The heat wrap material that raised the temperature of the pipe the quickest, reached the highest temperature, and sustained the highest temperature for an extended period of time the most effectively was Gore-tex.

The study defines a better design for the heat wrap and gives some indications of what results plumbers could expect in the field. Before going to market with the product, further testing would provide time and temperature tables for different size pipes based on the use of the heat wrap. Additional work could also provide a cost/benefit analysis for the product, which would be necessary to identify the market value of the heat-wrap.

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