The Effectiveness of a New Heat Wrap on PVC and CPVC Pipe Connections in Winter Conditions

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Winter conditions challenge the construction process in numerous ways. One challenge for plumbers is joining PVC and CPVC piping. As the temperature drops, the setting time for joints increases. The work process involves the sequential joining of pipes. With the longer setting time comes a danger of compromising the integrity of a joint connection while working on subsequent joints. Different methods have been employed to heat the pipes and connections to speed up the setting process. One solution is a "heat wrap" developed at a major university. The purpose of the heat wrap is to raise the temperature of the pipe and fitting to decrease the set of the solvent. This project provided a preliminary study to test the potential of the product to achieve the desired effect. The investigators have tested the effectiveness of the system by monitoring the heat transfer under defined climate conditions. Two sizes of pipe, 4-inch and 2-inch were tested. The results of the tests showed that the temperature of the pipe was raised enough to significantly lower the setting time for the solvent. The results of the study found that in-depth further studies are warranted. The patent process has been initiated.

Keywords: PVC, CPVC, solvent, cold weather, heat wrap

Introduction

The solvents used to join PVC and CPVC pipes are temperature sensitive, in that the setting time for the solvents increase significantly as the temperature drops. The increased setting time could become detrimental to the productivity and quality of plumbing work performed in winter conditions. The purpose of this study was to ascertain the effectiveness of a proposed heat wrap designed to increase the temperature of the pipe and fitting in order to decrease the setting time. The temperature of the heat wrap and the pipe were monitored to determine the change in the setting times. The tests were designed to determine whether further testing was warranted. Positive results in the initial tests would warrant continued and more intense testing. Negative test results would result in the re-examination of the product.

Background

Polyvinylchloride (PVC) was patented in 1913 by Fritz Klatte (PVC Industry). The use of PVC for pipe began in Europe and was first introduced in the United States in 1952: PVC is now the second most produced plastic. The world capacity for PVC production exceeds 31 million tons and is growing (Vinyl, Braun 2002). Over the past 55 years, PVC pipe has proven to be a durable, dependable, and cost-effective choice for both potable water and waste water, as well as agricultural and industrial applications (Braun 2002, PVC

Industry). PVC pipe is effective in a wide range of climates and conditions. The Waterworks, Waste, and Disposal Division of the City of Winnipeg uses PVC pipe in conditions that range from 90 degrees in the summer to minus 30 degrees in winter (McBride 1974).

PVC pipes and fittings are connected by the use of solvents which "weld" the pieces together, but cold weather provides challenges to the installers due to longer setting times. Cold weather conditions are unavoidable in many construction environments, so new products or methodologies can provide solutions to installers. The following study into the confounding factors of cold weather installations, which provides the background and parameters for the introduction and testing of a new product that may improve the PVC pipe and fitting assembly process. The product was tested under defined conditions to analyze the effectiveness of the product under cold temperature conditions. The goal is increase the PVC pipe temperatures to levels that allow rapid setting times.

The "Heat Wrap"

The "heat wrap" is a device designed to hold heat packs in place around the PVC pipe and fitting. The wrap consists of two layers of open-mesh fabric sewn together, with dividers to hold two heat packs in each section. The open mesh was required because the heat packs need air for the exothermic chemical process. The wrap was 6 inches wide and 32 inches long. A zipper along the length held the heat packs in the wrap, and Velcro strips along each side held the heat wrap in place on the PVC pipe.

In the present study, the "heat wrap" used chemical heating packs as the heat source. The packs were HotHands-2 hand warmers. The product was manufactured by HeatMax, and contains iron powder, water, salt, activated charcoal, and vermiculite. The chemicals are contained in a porous paper pack that is sealed in individual air-tight packages until the time of use. The exposure to air starts the chemical reaction which produces the heat. The manufacturer indicated that the packs would reach a temperature of 126-144 degrees F (HotHands-2).

The dividers in the heat wrap were designed to hold two HotHands-2 (2.25 inches x 4 inches) or 1 SuperHotHands (4 inches by 5 inches). The HeatMax products were chosen because of their national availability. The number of heat packs used depended on the size of the pipe. The 4 inch pipe required 10 packs and the 2 inch pipe required 6 packs.

Fundamentals of PVC and CPVC Pipe Joining

The understanding of cold weather installation problems for PVC and CPVC piping starts with the installation procedure. The process and solvent is the same for both the PVC and CPVC. Joint failures are seemingly rare, but there is no mechanism to collect failure data within the industry (Jayne 1983). The method of joining PVC and CPVC piping is generally the same as defined by ASTM, manufacturers of the pipe, and manufactures of the solvents. ASTM recommends following the manufacturer's specifications (ASTM).

The following is the joining process for PVC and CPVC as per Weld-On (commercial solvent) instructions under normal weather conditions (Weld-On).

- Apply the primer and solvent to both sides of the connection. See Figure 1.
- Assemble the pipe and fitting immediately, and make a 1/8 to ¼ twist while inserting the pipes. See Figure 2. The solvent penetrates the pipe surfaces and fuses the two pipes together as the solvent cures. See Figure 3.
- Handle the assembly carefully until the initial set time has been reached.

Figure 1 – Application of Solvent

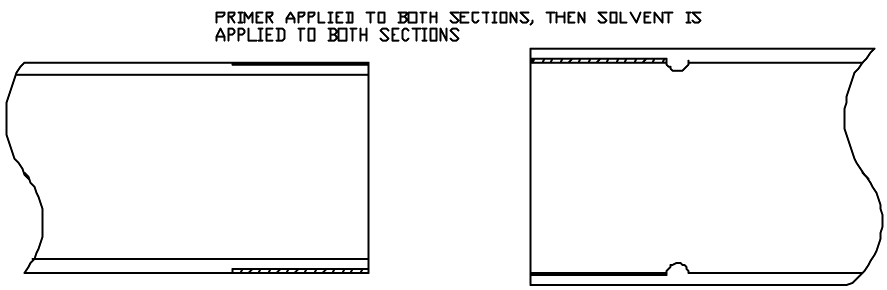


Figure 2 – Pieces Joined Together

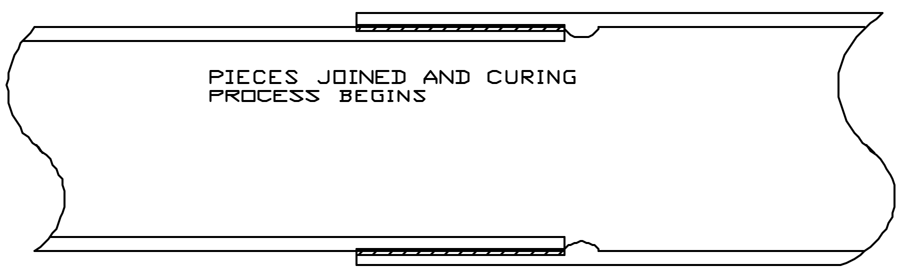
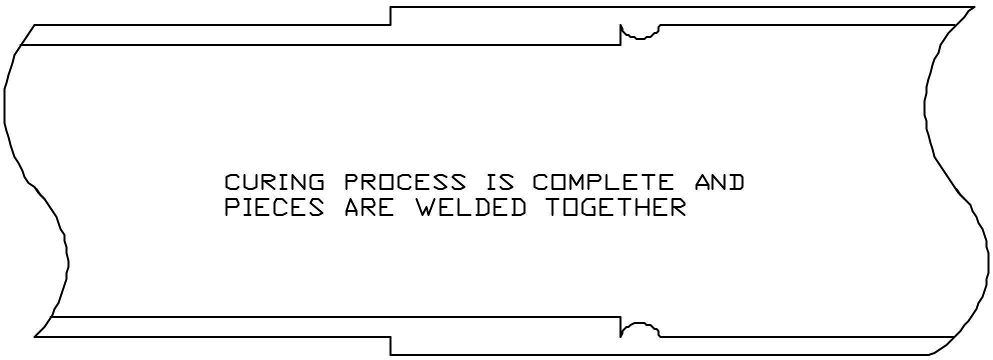


Figure 3 – Final Joint after Curing



Setting Time for Solvents

ASTM standard Designation: D 2855-96, recommends that the solvent manufacture's initial set schedule and cure schedule should be used (ASTM). The initial set schedule defines the period the joint needs to remain free of substantial movement to allow the solvent to attain the initial strength level. The cure schedule defines when the joint can be put under pressure. The initial set schedule for Weld-On PVC/CPVC Solvent Cements were typical of pipe and solvent manufactures' specification and ASTM specifications.

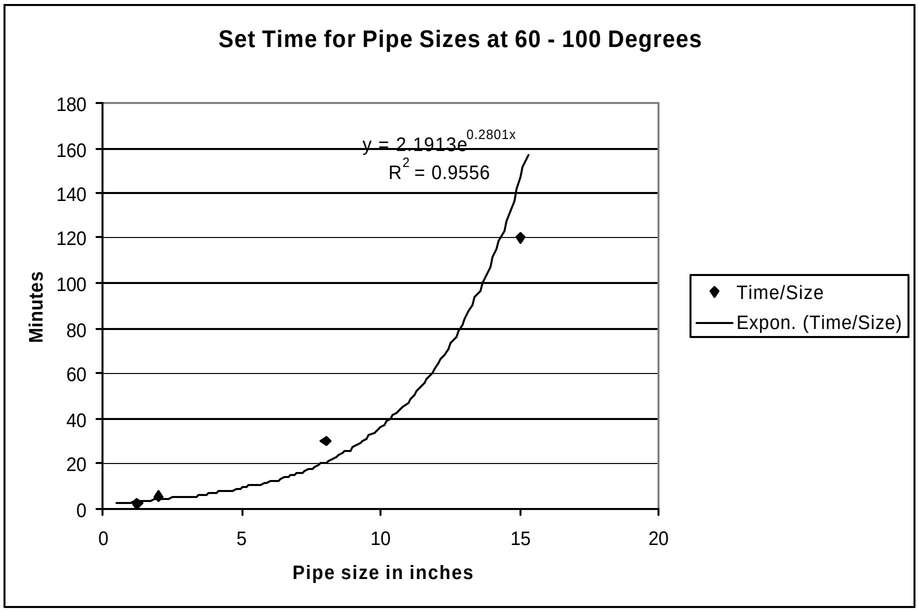
Table 1 – Average Initial Set Times for Weld-On PVC/CPVC Solvent Cements

Temperature Range Degrees F	Pipe Sizes In Inches ½ to 1 1/4	Pipe Sizes In Inches 1 ½ to 2	Pipe Sizes In Inches 2 ½ to 8	Pipe Sizes In Inches 10 to 15	Pipe Sizes In Inches 15 and over
60-100	2 minutes	5 minutes	30 minutes	2 hours	4 hours
40 -60	5 minutes	10 minutes	2 hours	8 hours	16 hours
0-40	10 minutes	15 minutes	12 hours	24 hours	48 hours

(IPS Weld-On)

Table 1 gives gave only three temperature ranges and setting times, based on groups of pipe sizes. The present tests were conducted on 4 inch and 2 inch pipe, so more accurate tables were necessary. The assumption was made that the manufacturer's table of values represented the worst case scenario for each pipe group and each temperature block. The pipe sizes were broken down to one quarter inch increments from one-half inch pipe to fifteen inch pipe and a trend line was found for each temperature block. Figure 4 shows the graph for the 60 to 100 degree block.

Figure 4 - Pipe Size Setting Time for 60-100 Degrees



The same method was used to arrive at the setting time for 4 inch pipe within each of the temperature blocks. The assumption that the manufacture's table of values assumes the worst case scenario for the block, the lowest temperature would be the critical value, and the critical value was used for the set time. Figure 6 shows the setting times for 4 inch pipe at the designated temperatures.

Table 2 – 4 Inch Pipe set Times at 0, 40, and 60 Degrees F

Basic Form Equation where y = initial set times $y = (K_1)*e^{K_2 x}$					
Temp	K1	e	K2	x	Set times
0	9.3448	2.718282	0.378	4	y = 42.4
40	4.2029	2.718282	0.3742	4	y = 18.8
60	2.1913	2.718282	0.2801	4	y = 6.7

The temperature blocks need to be divided into 10 degree increments for more accurate tracking of set times. Figure 5 uses the set times for 4 inch pipe at three temperatures (from Table 2) to determine the setting times along the trend line. Table 3 shows the setting times for 4 inch pipe at 10 degree increments. The same method was used to determine the setting times for 2 inch pipe, and those values are shown in Table 4.

Figure 5 – Set Time for 4 Inch Pipe

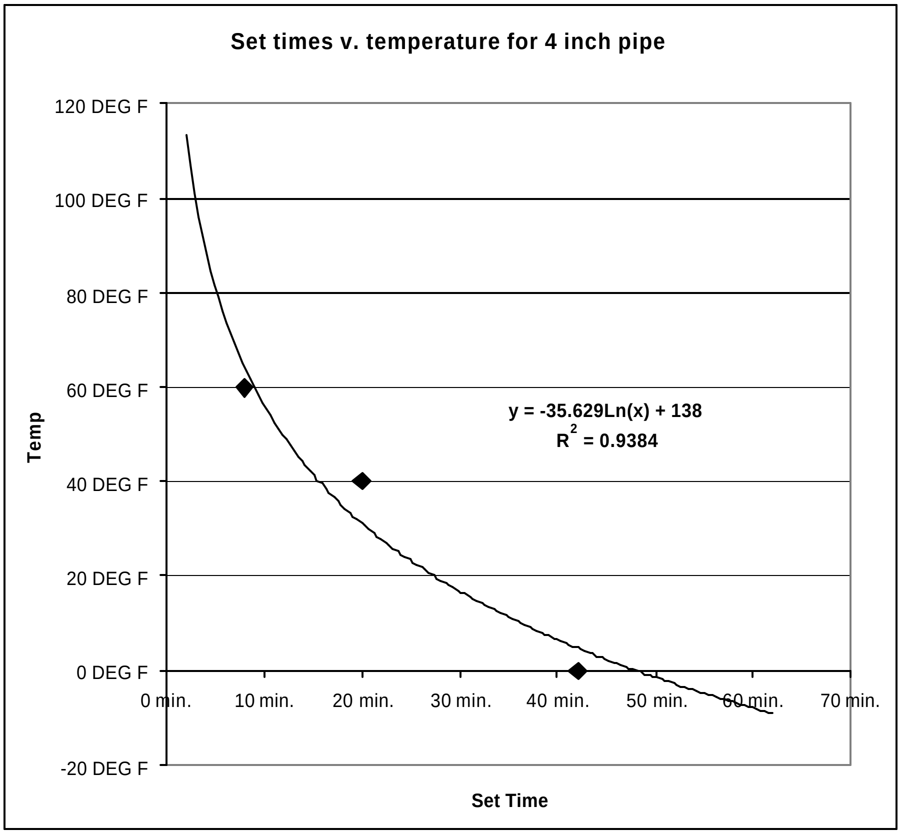


Table 3 – Setting Time for 4 Inch Pipe

Temperature	Setting Time
0 Degrees F	48 Minutes
10 Degrees F	36 Minutes
20 Degrees F	27 Minutes
30 Degrees F	21 Minutes
40 Degrees F	16 Minutes
50 Degrees F	12 Minutes
60 Degrees F	9 Minutes
70 Degrees F	7 Minutes
80 Degrees F	5 Minutes

Table 4 – Setting Time for 2 Inch Pipe

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

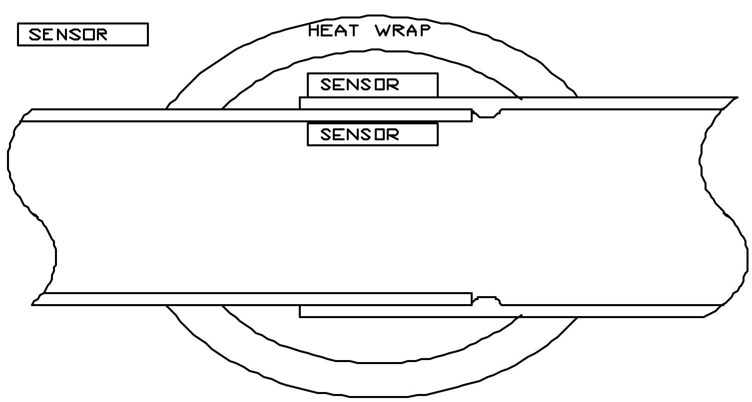
The impact of cold temperatures on pipe joints is not the ability to join in cold weather, but the time necessary to reach the “initial set” level. Reaching the initial set means that the pipe joint is stable enough for the worker to continue with subsequent joints without compromising the integrity of the previously completed joint.

Methodology

The methodology used to test the heat wrap consisted of simulating extreme outside conditions, applying the heating elements, and monitoring the temperature on the outside of the pipe directly under the heat wrap, and on the inside of the pipe. It was assumed that temperature on the inside of the pipe was the temperature at the surface where the pipes were being joined. The actual temperature at the surface where the joining was taking place would be higher, somewhere between the inside and the outside temperature, but that temperature at the joining surface could only be estimated and not measured.

Figure 6 shows how the sensors (data loggers) were placed on the inside and outside of the pipe. One sensor recorded the temperature under the heat wrap and a second that recorded the temperature of the pipe surface on the inside of the pipe. The third sensor was outside the pipe to measure the ambient air temperature.

Figure 6 – Placement of the sensors and the heat wrap



Recording the temperatures

The temperatures were recorded using Dickson SK 500 Data Loggers. The data loggers are sensors that record the temperature and humidity at preset intervals. The data were subsequently downloaded the DicksonWare software. The data loggers measure 1 inch x 1 ½ inch x 3/8 inch. For the testing in this experiment, the data loggers were set to record the temperature at five minute intervals

PVC Pipe and Fittings

Two sizes of PVC pipe diameter were used in the testing: 2 inch and 4 inch. The pipe tested was Schedule 40 PVC manufactured by J-M Manufacturing. The fittings used were 45 degree fittings. The pipe was cut into two feet long sections and prepared for joining as per manufacturer's recommendations, as noted above. The pipe was new and free of dirt or other debris.

Procedure

- The pipe, fitting and loggers were placed in a freezer for a period sufficient to bring the pipe temperature down to the freezer (ambient) temperature (0 degrees F).
- The heat wrap was applied to the joined area and left in the freezer.
- After 8 hours the loggers were removed and the data downloaded to record the results.
- The data were saved as Excel spreadsheets
- The process was repeated 6 times for each size pipe

Test Results

Figure 7 shows the results of the tests on 4 inch diameter pipes. The test results were recorded at five minute intervals, starting with the last recorded temperature before the temperature began to rise, and continuing for 8 hours. There were 96 data points on each test, and 6 tests were performed for each pipe size. Figure 7 illustrates the averages for each sampling time for the 4 inch pipe results. The pipe and ambient air temperatures were approximately 0 degrees when the heat wrap was applied. The data in Table 4 showed that the setting time at 0 degrees would be 48 minutes. Twenty minutes after the heat wrap was applied the inside temperature rose above 20 degrees F, and remained there for over two hours. If the pipe had been warmed for twenty minutes before the solvent were applied, and replaced after joining, the setting time would have been reduced to 27 minutes.

Figure 7 - 4 Inch Pipe Test Results

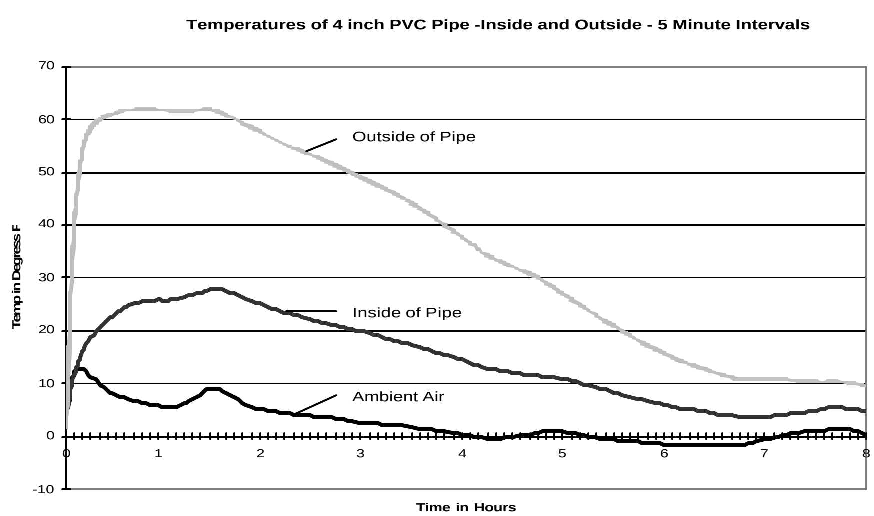
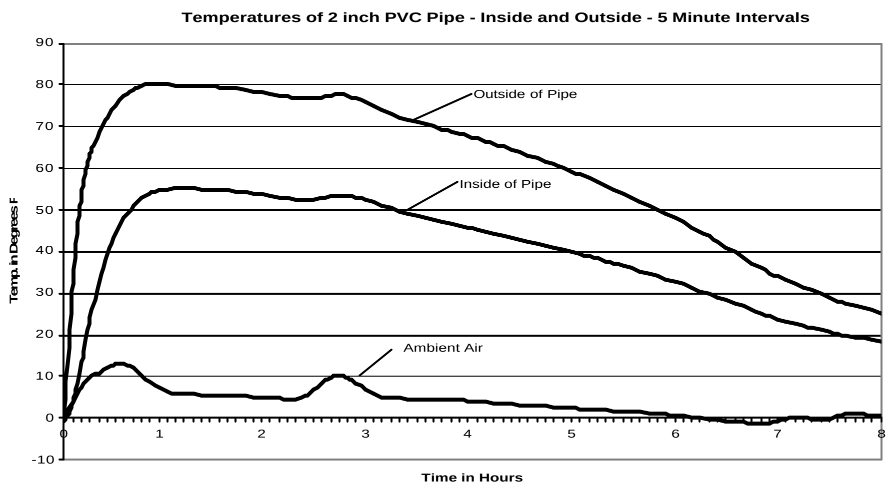


Figure 8 shows the results of the tests on the two inch pipes. At 0 degrees F, the 2 inch pipe requires 17 minutes of setting time. With the application of the heat wrap, the inside of the pipe reached 50 degrees, and the setting time was reduced to 7 minutes.

Figure 8 - 2 Inch Pipe Test Results



The differences between the 4 inch pipe and the 2 inch pipe were significant. The difference could have been due to the difference in the pipe wall thickness and the overall mass of the pipe. The low number of tests could skew results. There may also be a variation in the chemical reaction in the heat source.

Conclusion

The results of the testing showed that the temperature of the pipe was raised significantly as a result of the heat wrap. The increase in temperature significantly reduced the setting time required by the solvent. The heat wrap succeeded in decreasing the amount of time required for the solvent-bonded joint to set. The method of using chemical warmers, specifically HotHands-2, in conjunction with the heat wrap, was shown to be successful in the designed testing procedure. Further testing would be valuable in order to examine the heat wrap performance under other conditions. The tests were conducted at ambient air temperatures of 0 degrees F, which were on the extreme side of the working environment. Additional tests should be run at ambient temperatures above 0 degrees F, perhaps at 10 degree intervals to 40 degrees. The product could make a significant contribution to the construction industry by increasing the productivity of plumbers during winter conditions.

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