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Analysis of Chlorinated Polyvinyl Chloride Pipe Burst Problems: Vasquez Residence System Inspection

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Pipe Burst Problems:
Vasquez Residence System Inspection**

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Abstract

This report documents the investigation regarding the failure of CPVC piping that was used to connect a solar hot water system to standard plumbing in a home. Details of the failure are described along with numerous pictures and diagrams. A potential failure mechanism is described and recommendations are outlined to prevent such a failure.

Executive Summary

Sandia National Laboratories was contacted by Allsolar Energy Inc. of Deltona, Florida regarding the failure of Chlorinated Polyvinyl Chloride (CPVC) plumbing in homes that had been retrofitted with solar domestic hot water systems. The original home CPVC plumbing had been modified to attach the solar systems that used copper piping.

Allsolar has many years' of experience and was baffled at why the CPVC pipe had burst on the cold water supply lines. An initial pipe failure had been repaired and then the repaired pipe burst again. At this point the solar system was turned off and bypassed while Allsolar sought the solution to the CPVC pipe failures.

Sandia National Laboratories investigated the CPVC pipe failures with the assistance of the Florida Solar Energy Center (FSEC).

The CPVC pipe failure occurred on the cold water inlet pipe leading to the standard domestic hot water heater. The solar heating loop was connected directly to the inlet and outlet connections of the standard hot water heater using tee fittings. The thermal expansion of the hot water caused it to expand and back up into the inlet pipe, since the house side of the plumbing is a closed system and there was no expansion tank. The hot water exceeded the temperature and pressure limits of the CPVC pipe and the pipe bulged and burst.

Operating pressure for the system was the normal city water main pressure of 40 to 50 psi but that exceeded the operating parameters for CPVC at elevated temperatures. The operating pressure limits of CPVC approach 0 psi as the temperature approaches 210 degrees F.

Discussions with the CPVC manufacturer indicated this type of "bulging" failure is typical of over-temperature (greater than 200°F) at normal water line pressures. A failure mode due strictly to over-pressure at normal operating temperatures was eliminated since the pipe did not "crack" and burst in a way that indicates an overpressure failure. In addition, the home and the water meter did not have a back flow prevention device that would have allowed a large pressure increase during thermal expansion.

The following items are recommended to prevent this type of CPVC failure.

1. Install a check valve and expansion tank to control thermal expansion and keep the water from backing up into the CPVC cold supply. (May be required by code.)
2. Install a mixing valve to prevent extremely hot water from entering the home. (May be required by code.)
3. Remove the standard domestic hot water tank for single tank applications and install a tank designed for solar applications with multiple plumbing connections. This would prevent a direct path from the solar collector lines to the cold water supply line.
4. Possibly downsize the collector for 50-gal systems to prevent overheating.

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1. Background

In response to an inquiry from Sandia National Laboratories (SNL), Jim Huggins and John Harrison from Florida Solar Energy Center (FSEC) conducted a site visit to the Vasquez residence in Deltona, Florida to inspect the existing solar system and to gather information regarding the Chlorinated Polyvinyl Chloride (CPVC) pipe burst problems that occurred in April 2001.¹



Figure 1. Overall view of the tank area plumbing on July 18, 2001. Note that the pressure tank was removed from the system when the solar system was initially installed. The solar system was installed on April 9, 2001.

¹ Figures 1 through 3 were taken at the Vasquez site that experienced the CPVC piping system leaks. The FSEC provided photographs were taken on July 18 and 20, 2001. The photographs provided by the system owner and solar salespeople were taken at about the same time the events described occurred.



Figure 2. View of the flat plate collector July 18, 2001. Collector and ancillary valves were installed properly.



Figure 3. Additional view of the tank plumbing. July 18, 2001.

1.1 Chronology of the Investigation

The chronology of the CPVC piping problems at this residence follows.

1.1.1 February 2001

The Vasquez family moved into a new house.

1.1.2 April 9, 2001

The Allsolar Service installation crew installed the solar system. During the installation, the solar crew removed the existing expansion tank because, as the solar salesperson informed FSEC, he was told by the installer that “it was in the way of the solar plumbing.”

1.1.3 April 10, 2001

The first section of cold-water service CPVC line pipe burst (see Figure 4).

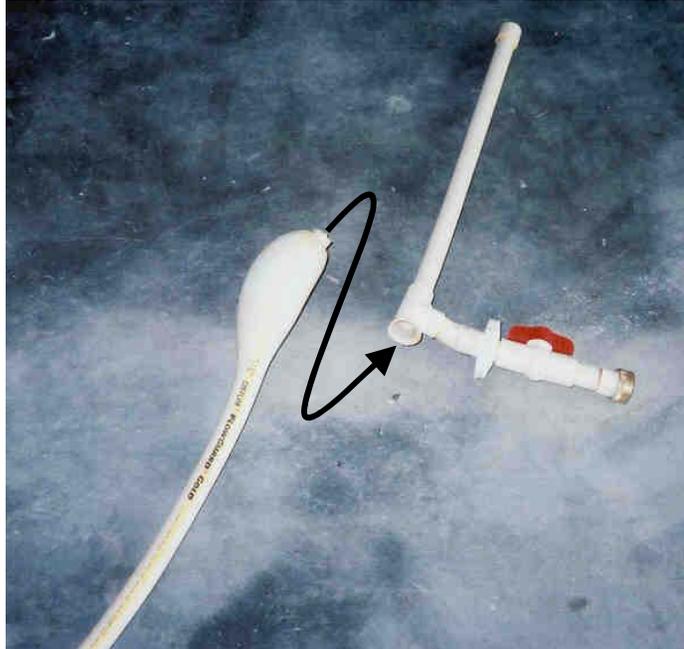


Figure 4. The section of pipe on the left with the balloon expansion is the first section of pipe that burst. The photograph indicates how the sections of piping were plumbed together. Note that the “bubbled” section of pipe was connected to the section of pipe on the right. This section, with the isolation valve, is the tee in the section that was located horizontally above the tank and plumbed into the collector feed line. Therefore, instead of a burst pipe, the two sections of piping shown above could have been separated from the coupling, which caused the leak.

The homeowner called the plumber who had originally installed the cold-water service CPVC line plumbing. The plumber repaired the broken pipe. It appears from a photograph (Figure 4) provided by Mrs. Vasquez that the plumber removed the horizontal cold-water service line above the water heater while repairing the leak in the vertical cold-service line between the wall (garage and bedroom). In any event, at this point, the plumber re-plumbed the horizontal section of the cold-water service line with the isolation valve. It is not known whether he also incorporated the existing water hammer trap as well. According to the homeowner, the section reinstalled by the plumber did not have the water hammer pipe – only the isolation valve. Mr. Vasquez stated that the water hammer section was not there when he repaired the second leak at the fitting. A fitting was used in the isolation valve that connected directly to a brass fitting. It was this connection that failed in the second pipe burst.

1.1.4 April 11, 2001

A City of Deltona building official inspected the solar system and stated that all was fine, and the system passed. Mrs. Vasquez (in conversation with FSEC staff) stated that the building official told her that the city only recently started requiring expansion tanks and that he had not seen any problems without them before. It is believed that he was referring to standard cold-water service systems – not the solar system installed.

1.1.5 April 12, 2001

The solar salesperson informed FSEC that on this day, another section of cold-water service CPVC line burst (see Figure 5 for the location of the second leak).

Further discussion with Mr. Vasquez on the evening of 19 July 2001 revealed that a pipe did not burst – instead, a fitting on the horizontal cold-water service line came apart. (See Figures 5, 6, and 7.) This was the “pipe leak” referred to by the solar salesperson. Mrs. Vasquez nevertheless indicated that a small section of pipe not far from the fitting (to the left of the isolation valve) did exhibit “some small swelling on the bottom of the pipe.” Note that this might have occurred with the first leak, since both may have been a fitting separation that included pipe expansion in the close vicinity of the separation. Mr. Vasquez felt that the plumber who had reworked this plumbing after the first leak did an inadequate job with the fitting connection.



Figure 5. This photograph was taken by the homeowner after the second leak shows the coupling that separated from the pipe union. Once this happened, a tremendous amount of water poured into the garage.

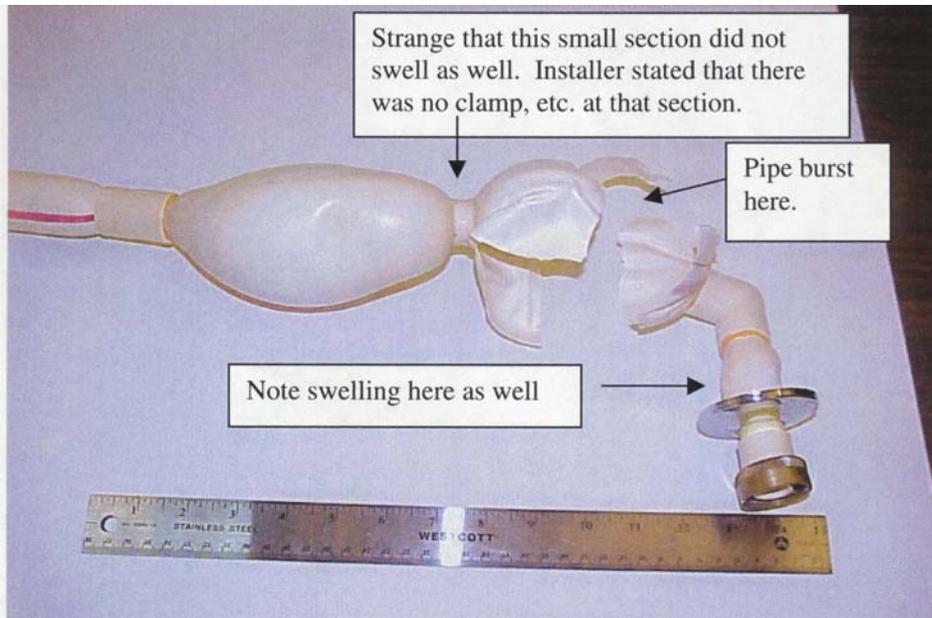


Figure 6. House X piping cold feed line.

Markings on long section of piping: 3/4 in., CPVC Coastline Premium, CPVC 4120, SDR11, NSF-pw, 100 psi at 180°F, 400 psi at 73°F, ASTM D2846, B1, Made in USA, 14APR97, 233804, 2338, shift 33, Potable Water. Markings on bubble/burst section of piping (that could be made out): Made in USA, 15APR97, 095514, 0955, Shift 02, Potable Water

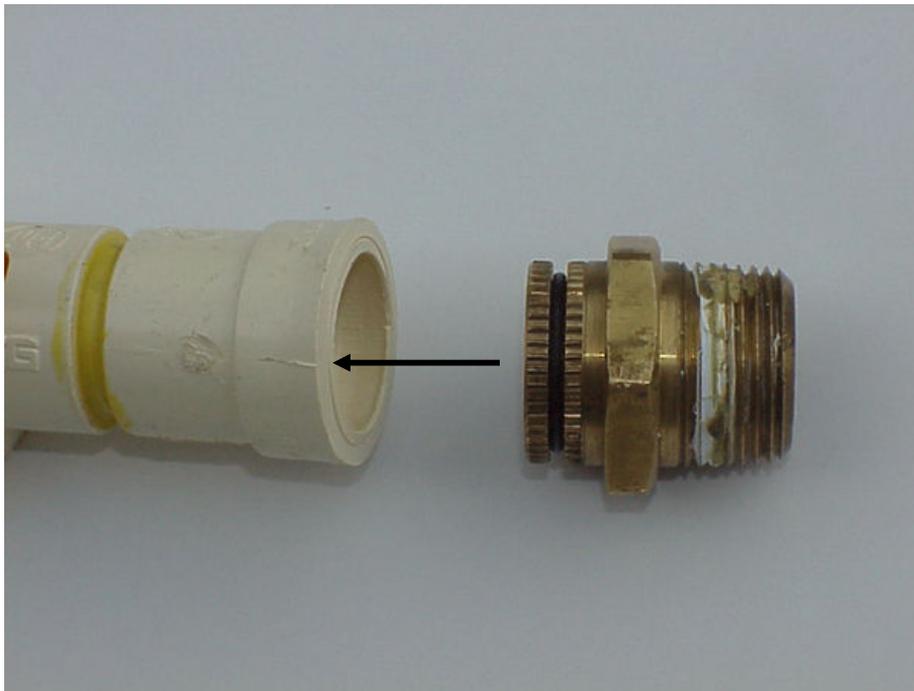


Figure 7. Close-up of the union that came apart and caused the second leak on July 20, 2001. (Actual components were provided by Mr. Vasquez to FSEC staff.) The brass section with the o-ring does not, at this time, fit into the opening of the CPVC pipe section. A check of plumbing catalogs indicated that CPVC couplings with brass connectors are available.

The plumber that installed the water heater plumbing during construction of the house repaired the initial leak on the same day it occurred. The plumber stated that he was going to send the damaged section (assumed to be the bubbled section in Figure 4) out for testing. Results were never obtained from the plumber.

The homeowner called the plumber to have the leak repaired. The plumber refused to come back out and make any repairs, claiming that since the solar installer had removed the expansion tank, this voided any plumbing warranty.

The homeowner, therefore, conducted the repairs himself with materials purchased at a local hardware store. This included CPVC piping, as well as a new fitting. Please see Figures 8, 9, 10, 11, 12, 13, and 14 for further information.

Mr. Vasquez re-plumbed the horizontal section of pipe. This included new CPVC and a new fitting for the point where the CPVC pipe is attached to the copper pipe. FSEC staff were informed that he cut the piping in the vertical run inside the wall and replaced the piping from there to the copper fitting. He also removed the cold service isolation valve.

1.1.6 April 13, 2001

The solar installer returned and reinstalled an expansion tank. The installer also deactivated the system.

Since then, the solar system has been deactivated. Mr. and Mrs. Vasquez are currently waiting to see if anything can be determined. Mrs. Vasquez informed FSEC staff that eventually they will have to file for insurance damage since expenses and losses were incurred during both leaks.

It should be noted that the solar installer also installed a solar pool heating system at this residence. There have been no problems with the solar pool heating system.



Figure 8. Close-up view of the tank plumbing on July 18, 2001.

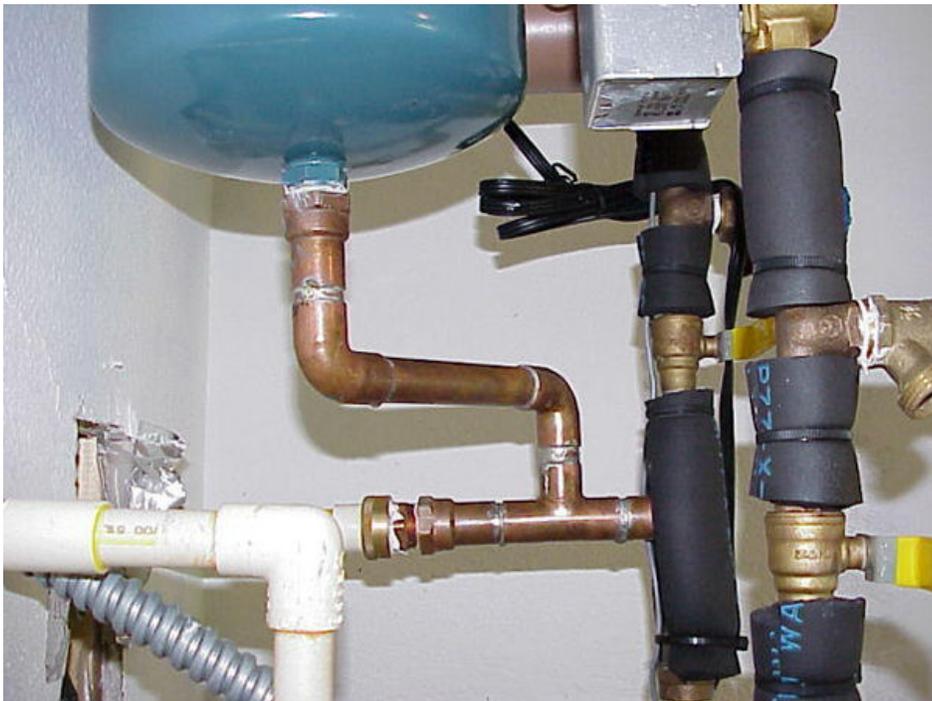


Figure 9. Close-up view of the tank plumbing on July 20, 2001.



Figure 10. Another close-up view on July 20, 2001.



Figure 11. View of the approximate area where the first piping system leak occurred on April 10, 2001, as seen from the tank side. Note the coupling at the bottom of the picture. It is believed that this coupling was used by Mr. Vasquez to repair the second leak. (July 18, 2001)



Figure 12. View of the approximate area where the first April 4, 2001 pipe burst occurred, as seen from the bedroom wall side. The plumber had to cut away the bedroom wall almost to the floor to repair this first leak. Note the straight coupling at the bottom of the picture. This coupling is believed to be the coupling that Mr. Vasquez procured and installed when repairing the piping after the second leak. (July 18, 2001)



Figure 13. This is the fitting that Mr. Vasquez replaced himself after the plumber refused to fix the second leak. (July 20, 2001)



Figure 14. Note the CPVC couplings with the register scan tags. From telephone conversations with Mr. Vasquez, it is believed that this is the location where Mr. Vasquez cut the line to plumb the new section after the second leak. He replaced the whole line from the bottom coupling to the CPVC/brass connector on the horizontal line. (July 20, 2001)

2. System and Site Inspection

2.1 System type

All Solar Energy, Deltona, Florida, installed a solar water heating system on the Vasquez residence on April 9, 2001. The system was an active, direct system retrofitted to the existing electric water heater. The system consisted of the following components

2.2 Collector Area

American Energy Tech AE-32 (32 ft²) collector mounted at a 20-degree tilt, 30 degrees east of south orientation. No shading.

Standard pressure relief valve (125 psi)

Air vent, Amtrol

Eaton freeze prevention valve

2.3 Tank Area

A.O. Smith, Energy Saver, EEST-52T-920, 50-gallon electric water heater

Independent Energy GL 30-LCO using 10K sensors

TACO 003-BC4 pump

Motorized check valve (Honeywell type)

Collector feed and return line isolation valves (ball)

Collector feed and return line drain valves (standard hose bibs)

½ in. Copper collector feed and return lines

¾ in. CPVC piping for cold service line and hot outlet line

Water meter in front yard. No backflow preventer in service line from water meter to house.

The system was shut down during the FSEC inspection. The solar installer had deactivated the system after the second pipe burst.

2.4 Differential Controller

The controller differential was set at 8°F. The high temperature limit was set at 160°F. It is unclear whether these were the settings when the system was initially activated, but more than likely they were. The range on this particular controller is 8 to 24°F for differential “On” and 105 to 200°F for high temperature control. The sensor at the bottom of the water heater tank is used to determine when the high limit is reached.

FSEC staff conducted a test of the differential controller using an FSEC-designed differential controller test device. FSEC staff also conducted a resistance test of the sensors and sensor wiring (tested together). The resistance figures were reasonable. Testing of the controller indicated that all controller functions worked properly. Functions checked included controller differential settings, the high temperature limit, and the freeze feature.

Although the controller tests did not indicate any problems during the testing procedures, FSEC believes that there is a problem with this controller. The controller exhibited erratic behavior (turning on and off) while FSEC staff were at the site. The solar system was

deactivated and there was no water in the collector loop. During the site visit, FSEC plugged the controller into a power source. (The pump was disconnect from the controller.) FSEC determined that the collector and tank sensor temperature differential was large enough (collector: 195°F, tank: 82°F) during the site visit that the controller should have activated the pump circulation mode continuously. However, the controller output turned off and on several times while the FSEC staff were there – even though the collector and tank sensor differential temperature quite exceeded the controller’s differential “On” set point. This would tend to indicate a problem with this controller.

2.5 Electric Water Heater

The water heater is currently activated and is being used by the homeowner. Both upper and lower thermostats and elements seem to be operational. An inspection of the tank thermostats indicated that the lower thermostat was set at 100°F while the upper was set at 125°F. It is unclear whether these were the settings in place when the pipe bursts occurred.

2.6 Tank Sensor

The tank sensor was properly mounted in the tank. A check of the tank sensor (including wiring) from the controller indicated a resistance of 8.9 K ohms (82°F).

2.7 Pump

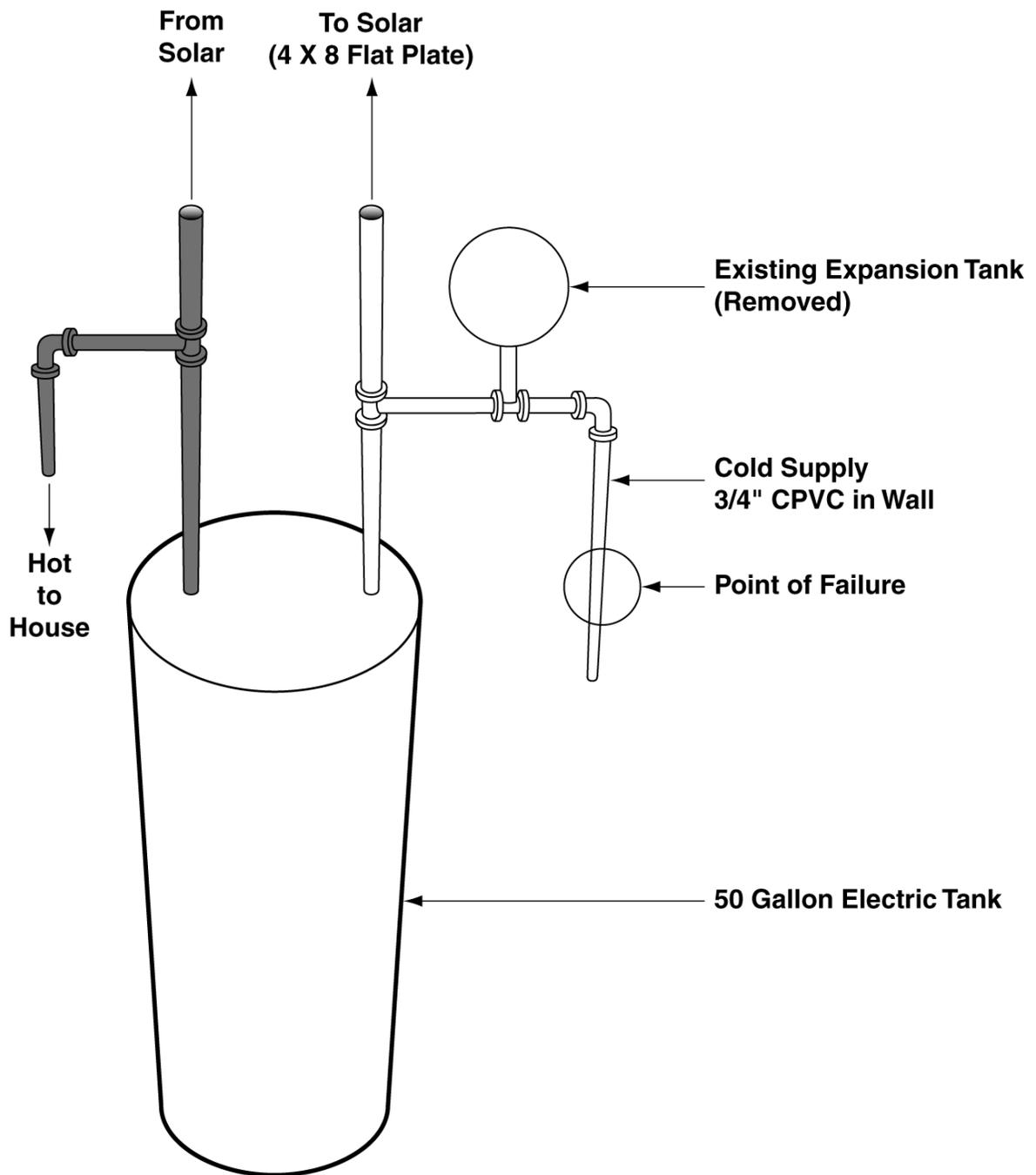
FSEC staff connected the pump to the controller and activated the controller for a second. The pump, although dry, appeared to be operational, judging from the sound and vibrations.

2.8 Motorized Check Valve

Was not checked since system was inoperative and inspectors would have had to turn the pump on for quite some time in a dry condition.

2.9 Expansion Tank

An expansion tank was installed. Note that the solar installer had removed the existing expansion tank when the solar system was installed. The solar installer installed a new expansion tank after the second pipe burst. The current expansion tank is a Water Worker G-5 Safety Tank with a 40-psi pre-charge (see Figure 15).



Solar high limit set to 155°
 Electric T-STAT set to 130°
 House plumbed in 3/4" CPVC

Figure 15. Installation drawing.

2.10 CPVC Piping

Charlotte Pipe (brand), $\frac{3}{4}$ in.

2.11 Collector Feed and Return Lines

Copper piping, $\frac{1}{2}$ in.

2.12 Piping Insulation

Rubatex $\frac{1}{2}$ in. wall thickness pipe insulation. The piping was not completely insulated. See Figures 16 and 17.

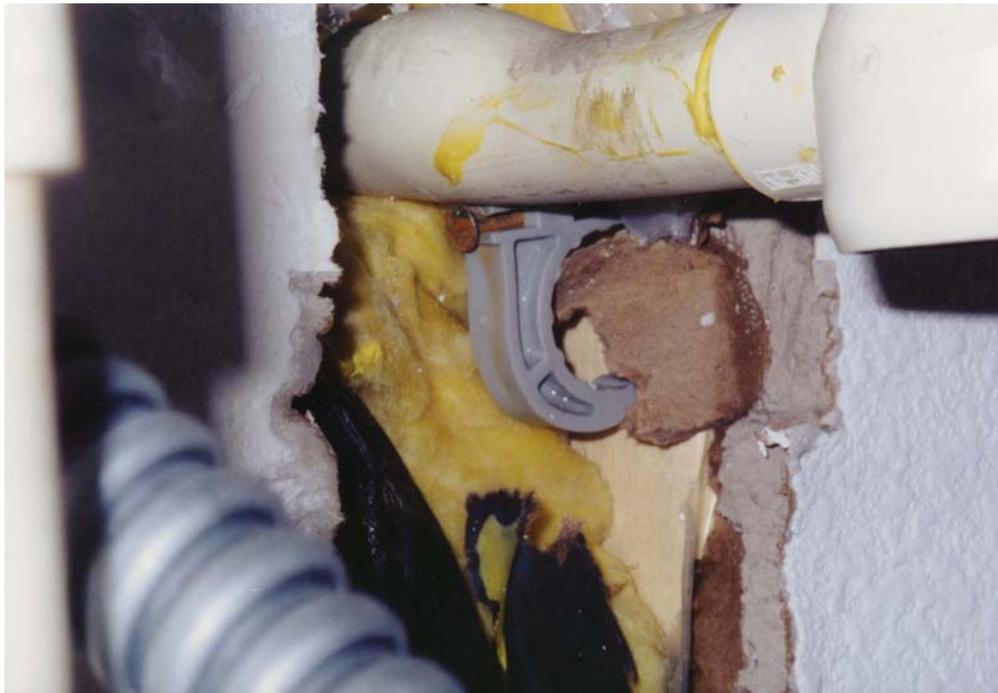


Figure 16. Insulation adjacent to pipe.

2.13 Collector

An inspection of the collector mounting revealed that the collector mounting and pipe penetrations were suitable. The collector was mounted with the long axis in a horizontal position. The collector was also mounted with a drain tilt adequate for collector drainage.

2.14 Collector Sensor

The collector sensor was properly connected to the collector outlet piping immediately adjacent to the solar collector. However, the sensor was exposed to the environment – that is, it was not covered with insulation. The system salesperson was informed of this and told to have it corrected. A check of the sensor (including wiring) from the controller indicated a resistance of 0.9 K ohms (195°F).

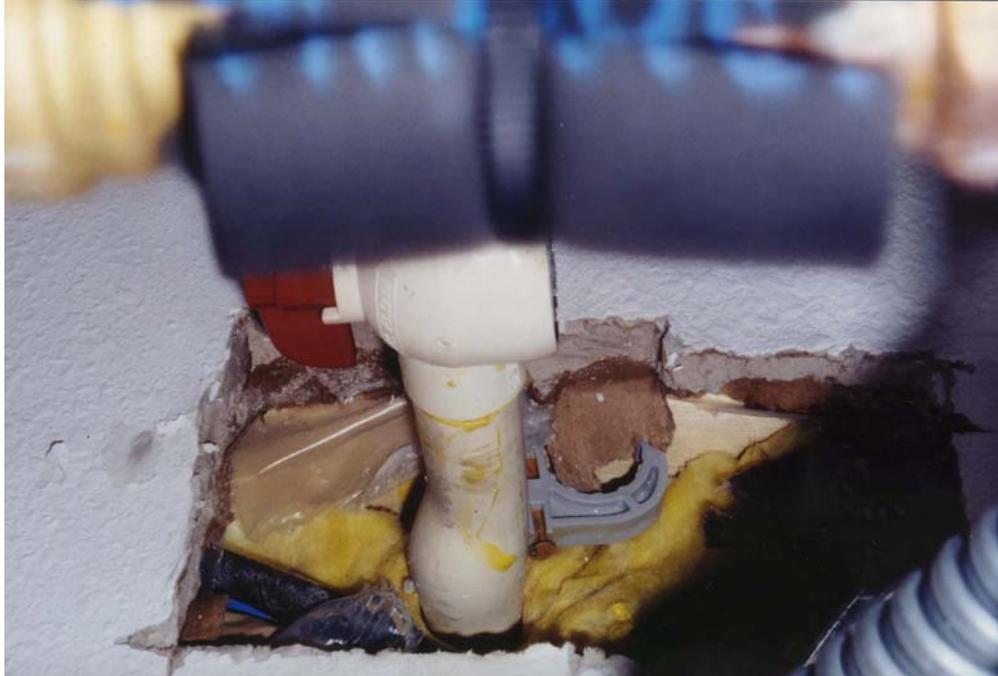


Figure 17. Insulation was not completely installed.

2.15 Collector Valves

The air vent, pressure relief, and freeze valve were properly installed. The freeze valve was installed with an uninsulated 6 in. copper leg. This was done to prevent heat damage during the summer, and also to sense ambient temperatures during winter months. The leg could have been extended to a length of 12 to 16 in., but this was not immediately critical.

2.16 Additional Information

The solar salesperson took FSEC staff to a second house in which the cold inlet CPVC piping had also burst. The resident was not at home; therefore, it was impossible to inspect the system.

In this case, the solar system had been in for approximately one year before the pipe burst. The pipe burst at this site occurred on the cold inlet service piping in a vertical pipe section similar to that indicated in Figure 9. The pipe break occurred in a lower area of the vertical pipe (about 18 in.) than at the Vasquez residence. The pipe leak was repaired. It has been over 1.5 years since this problem occurred, and there have been no further problems with the piping. The solar system has remained in service since it was installed.

3. Conclusions and Recommendations

3.1 Conclusions

The CPVC pipe failure occurred on the cold water inlet pipe leading to the standard domestic hot water heater. The solar heating loop was connected directly to the inlet and outlet connections of the standard hot water heater using Tee fittings. The thermal expansion of the hot water caused it to expand and back up into the inlet pipe since the house side of the plumbing is a closed system and there was no expansion tank. The hot water exceeded the temperature and pressure limits of the CPVC pipe and the pipe bulged and burst.

The operating pressure was the normal city water main pressure of 40 to 50 psi but that exceeded the operating parameters for CPVC at elevated temperatures. The operating pressure limits of CPVC approach 0 psi as the temperature approaches 210 degrees F. Reference CPVC specifications section 4. The pipe failed by bulging rather than cracking as shown in Figure 4 and 6.

Discussions with the CPVC manufacturer indicated this type of bulging failure is typical of over-temperature (greater than 200°F) at normal water line pressures. A failure mode due strictly to overpressure at normal operating temperatures was eliminated since the pipe did not “crack” and burst in a way that indicates an overpressure failure. In addition, the home and the water meter did not have a back flow prevention device that would have allowed a large pressure increase during thermal expansion.

The thermal expansion of the heated water in a 50-gallon tank is approximately 0.47 gallon with a conservative delta T of 80°F. Thermal expansion calculations are included in Section 4.

If there are no faucets open in the house and there is no expansion tank or check valve (as indicated in this home), then that 0.47 gal has to back up into the cold supply line or be vented by the temperature and pressure (T&P) valve (see Section 4.3). There was no check valve on the supply and no venting was noticed at the T&P valve. Very hot water (in the 200°F range) had to be backing up into the CPVC cold supply line.

The expanded volume of 0.47 gallons could back up into ½ inch CPVC a distance of up to 31.4 ft and up to 17.7 ft for ¾ inch CPVC. This indicates how the hot water got into the cold supply. It's difficult to predict what the exact hot water path of flow is between the tank, the collector, the way it is plumbed with a standard water heater, if heat traps on one of the tanks contributed, and if the motorized solar check valve was working, but the result is that hot water was forced into the cold supply line.

It is not known if the solar controller failed to shut off at the upper limit. The high temperature sensor located in the bottom of the tank was set at 160°F which will still allow considerably higher temperatures at the top of the tank. The controller could have shut off properly and the stagnated super-heated water from the collector backed up into the cold line since the collector line was tee'ed directly to the cold inlet line. This type of plumbing

connection may have prevented the T&P relief valve from sensing the high temperatures, assuming the T&P relief valve was operating properly. Any type of pressure reduction on the city supply would also cause water to back up into the supply line.

3.2 Recommendations

1. Install a check valve and expansion tank to control thermal expansion and keep the water from backing up into the cold supply. (May be required by code)
2. Install a mixing valve to prevent extremely hot water from entering the home. (May be required by code)
3. Remove the standard domestic hot water tank for single tank applications and install a tank designed for solar applications with multiple plumbing connections. This would prevent a direct path from the solar collector lines to the cold water supply line.
4. Possibly downsize the collector for 50-gal systems to prevent overheating.
5. Note: Threaded CPVC connections are not recommended for elevated temperature applications.

4. Product Specifications

4.1 CPVC

4.1.1 Product Name

Chlorinated Polyvinyl Chloride (CPVC) Plastic Pipe and Fittings for Hot and Cold Water Distribution Systems.

4.1.2 Manufacturer

For a list of member manufacturers, contact the Plastic Pipe and Fittings Association, 800 Roosevelt Road, Building C, Suite 20, Glen Ellyn, IL 60137; (630) 858-6540; fax (630) 790-3095; www.ppfahome.org.

4.1.3 Product Description

Basic Use: Hot and cold water distribution systems, including water recirculation lines. CPVC pipe can be used in residential, commercial, and industrial applications. CPVC pipe and fittings are resistant to potable water disinfectants, such as chlorine, chloramine, and ozone.

Pipes and fittings are joined by solvent cementing. A full complement of fittings, valves, and pipe is available for potable water applications. Pipes and fittings are available in Copper Tube Size (CTS) 1/2 through 2 in., and in Iron Pipe Size (IPS) 1/4 through 12 in. CPVC pipe and other piping materials are connected with adapter fittings, which utilize threaded joints, compression connections, flanges, or mechanical connections.

Composition and Materials: CPVC is a thermoplastic material. The CPVC compounds meet the requirements of Class 23447, as referenced in ASTM D 1784.

Grades: CPVC pipes and fittings are made from CPVC compounds. CPVC CTS SDR 11 pipe and fittings (ASTM D 2846) are used in these systems. CPVC IPS pipe is available as schedule 40 and 80 or SDR-PR pipe. The CTS pipe has the same outside diameter as copper tube. The IPS pipes have the same outside diameter as the corresponding sizes of steel pipe. CTS is available in sizes 1/2 through 2 in. For installations larger than 2 in., Schedule 40, Schedule 80, and SDR-PR pipe is available in sizes up to 12 in.

Limitations: SDR 11 CTS CPVC pipe and fittings are pressure rated for continuous use at 400 psi at 73.4°F and 100 psi at 180°F. Each size of the schedule 40 and 80 pipe has a different pressure rating, and as the temperature increases, the pressure rating decreases. Under no circumstances should temperature exceed 212°F for pressure piping, but CPVC temperature/pressure relief discharge pipes have been tested at 250°F.

Plastics are affected by ultraviolet radiation. Pigments are added to the CPVC materials to shield them from radiation effects. CPVC piping can be exposed to sunlight during construction; however, prolonged exposure to the sun is not advised unless protected by a water-based latex paint.

4.1.4 Technical Data

Applicable Standards: ASTM D 2846 or CSA CAN/CSA B137.6 apply to CPVC SDR 11 (CTS) pipe and fittings. ASTM F 441 applies to Schedule 40 and 80 pipe. ASTM F 442 applies to SDR-PR pipe. ASTM F 438 applies to Schedule 40 socket fittings. ASTM F 439 applies to schedule 80 socket fittings. ASTM F 493 applies to solvent cements for CPVC.

Quality Control: Most pipe and fittings are evaluated and listed by an ANSI-accredited third-party listing agency (e.g., NSF or UL). These agencies certify CPVC piping as conforming to ANSI/NSF 14 and 61 for use in potable water systems and for strength and durability requirements. Contact the manufacturer for more information.

Chemical Resistance: CPVC pipe and fittings are resistant to chemicals used in disinfecting potable water. CPVC pipe resists certain chemical actions on the exterior of the pipe when located in hazardous environments. Contact the manufacturer for a detailed list of chemicals CPVC pipe can resist.

Flow Characteristics: CPVC pipe does not corrode or accumulate mineral deposits. CPVC pipe should be designed with a water flow rate between 5 to 12 feet per second. See Table 1. Water velocities in excess of 5fps are not recommended for large diameter (greater than 6 in.) IPS CPVC systems.

Table 1. Frictional Losses for CTS CPVC Pipe at Different Water Velocities

VELOCITY (fps)	1/2 in. CTS			3/4 in. CTS			1 in. CTS		
	FLOW (gpm)	HEAD LOSS* (feet)	HEAD LOSS* (psi)	FLOW (gpm)	HEAD LOSS* (feet)	HEAD LOSS* (psi)	FLOW (gpm)	HEAD LOSS* (feet)	HEAD LOSS* (psi)
2	1.14	4.28	1.86	2.47	2.78	1.20	4.11	2.07	0.90
4	2.29	15.56	6.75	4.94	10.02	4.34	8.22	7.47	3.24
5	2.87	23.64	10.25	6.17	15.12	6.55	10.27	11.28	4.89
6	3.44	33.07	14.34	7.40	21.18	9.18	12.32	15.81	6.85
8	4.59	56.41	24.45	9.87	36.10	15.65	16.43	26.94	11.68
10	5.74	85.35	37.00	12.34	54.49	23.66	20.54	40.73	17.66
12	6.89	119.77	51.92	14.81	76.58	33.20	24.65	57.27	24.83
VELOCITY (fps)	1 1/4 in. CTS			1 1/2 in. CTS			2 in. CTS		
	FLOW (gpm)	HEAD LOSS* (feet)	HEAD LOSS* (psi)	FLOW (gpm)	HEAD LOSS* (feet)	HEAD LOSS* (psi)	FLOW (gpm)	HEAD LOSS* (feet)	HEAD LOSS* (psi)
2	6.14	1.64	0.71	8.58	1.34	0.58	14.72	1.02	0.44
4	12.28	5.93	2.57	17.17	4.84	2.10	29.44	3.68	1.60
5	15.36	8.98	3.89	21.46	7.31	3.17	36.81	5.56	2.41
6	18.43	12.58	5.45	25.75	10.25	4.44	44.17	7.80	3.38
8	24.57	21.42	9.29	34.34	17.47	7.57	58.89	13.28	5.76
10	30.71	32.38	14.04	42.92	26.40	11.44	73.61	20.08	8.71
12	36.85	45.29	19.63	51.50	37.00	16.04	88.33	28.16	12.21

*Head Loss/100 ft. of pipe

Friction loss for flow through fittings is based on equivalent length of pipe. Equivalent lengths of pipe for CTS fittings ½ through 2 in. are shown in Table 2. Consult the manufacturer’s published tables for dimensions, friction loss data, and equivalent length of pipe for IPS schedule 40 and schedule 80 fittings.

**Table 2. Approximate Equivalent Length of Pipe (ft)
CPVC SDR 11 (CTS) Pipe Fittings**

Pipe Size (in.)	90° Elbow	45° Elbow	Through Tee Run	Through Tee Branch
1/2	1.6	0.8	1.0	3.1
3/4	2.1	1.1	1.4	4.1
1	2.6	1.4	1.7	5.3
1 1/4	3.5	1.8	2.3	6.9
1 1/2	4.0	2.1	2.7	8.1
2	5.2	2.8	3.5	10.3

Water Hammer: Intensity of water hammer in CPVC pipe is approximately 1/3 the intensity of copper or steel pipe.

Laying Lengths: CPVC pipe is available in 10- and 20-ft lengths. The smaller sizes (1 in. max.) of CPVC CTS are also available in coils. Minimum laying lengths for CPVC SDR 11 (CTS) fittings are identified in Table 3.

Table 3. Minimum Laying Lengths of CPVC CTS Pipe Fittings (in.)

Nominal Pipe Size (in.)	Elbow G	45° Elbow J	Tee G	Coupling N
1/2	0.382	0.183	0.382	0.102
3/4	0.507	0.235	0.507	0.102
1	0.633	0.287	0.633	0.102
1 1/4	0.758	0.339	0.758	0.102
1 1/2	0.884	0.391	0.884	0.102
2	1.134	0.495	1.134	0.102

Expansion and Contraction: CPVC pipe has a higher coefficient of expansion and contraction than metallic pipe. The coefficient of linear expansion for CPVC plastic is 0.000034 in./in./°F. This translates into an expansion of 2.04 in. for every 50 ft with a temperature change of 100°F.

Where CPVC pipe is installed in long straight lengths, compensation for expansion and contraction must be provided. This can be accomplished at changes in direction or with offset piping arrangements such as loops or bends, so that pipe flexibility provides for thermal expansion.

Hangers and Supports: CPVC pipe must be supported at 3-ft intervals for pipe 1 in. and less in diameter and 4-ft intervals for pipe 1 1/4 to 2 in. For larger sizes of schedule 40 and 80 pipe, consult the tables above. Vertical pipe shall be supported at each floor level with mid-story guides. Where the design engineer has made provisions for expansion, they must be followed. Install hangers and supports to allow for thermal expansion and contraction. Avoid the use of hangers and support that contain chemicals which are known plasticizers.

Fire Protection: CPVC pipe and fittings may be used in residential, commercial, and industrial buildings, even those that require non-combustible construction.

Through penetrations of fire resistance-rated assemblies by CPVC pipe are accepted in the model building codes when such assemblies have successfully met the requirements of ASTM E 814. These penetration assemblies are listed by ANSI-accredited testing agencies such as UL and Intertek. Verify local code interpretation related to through penetrations with the jurisdiction having authority. Refer to the local building department for regulations concerning use of CPVC pipe and fittings.

Flame Spread and Smoke Developed Rating: When tested in an ASTM E 84 tunnel, water-filled CPVC pipe (2.5 in. and smaller) had a flame spread of 25 or less and smoke developed rating of 50 or less. Contact pipe manufacturers for additional information.

4.1.5 Temperature Pressure De-rating

CPVC Thermoplastic Material Temperature Pressure De-rating

Elevated temperature fluid mediums require a de-rating of thermoplastic pipe maximum internal pressure ratings at 73°F. To determine the maximum internal pressure rating at an elevated temperature, simply multiply the product pressure rating at 73°F by the percentage specified for the desired temperature.

System Operating Temperature °F (°C)	73-80 (23-27)	90 (32)	100 (38)	110 (43)	120 (49)	130 (54)	140 (60)	150 (66)	160 (71)	170 (77)	180 (82)	190 (88)	200 (93)	210 (99)
CPVC	100%	92%	82%	77%	65%	62%	50%	47%	40%	32%	25%	22%	20%	-0-

NOTE: Threaded CPVC products should not be used at temperatures above 150°F (66°C). Valves, unions and specialty products have different elevated temperature ratings than pipe and fittings.

CPVC Basic Physical Properties

Properties	ASTM Test Method	CPVC
Mechanical Properties, 73°F		
Specific Gravity, g/cm ³	D 792	1.55
Tensile Strength, psi	D 638	8,000
Modulus of Elasticity, psi	D 638	360,000
Compressive Strength, psi	D 695	10,100
Flexural Strength, psi	D 790	15,100
Izod Impact, notched, ft-lb/in	D 256	1.5
Thermal Properties		
Heat Deflection Temperature, °F at 66 psi	D 648	217
Thermal Conductivity, BTU/hr/sq ft/°F/in	C 177	.95
Coefficient of Linear Expansion, in/in/°F	D 696	3.4 x 10 ⁻⁵
Flammability		
Limiting Oxygen Index, %	D 2863	60
UL 94 Rating		V-0, 5VB, 5VA
Other Properties		
Water Absorption, % 24 hr.	D 570	.03
Industry Standard Color		Medium Gray
ASTM Cell Classification	D 1784	23447
NSF Potable Water Approved		Yes

CPVC Chemical Resistance

Weak acids	Excellent
Strong acids	Excellent
Weak bases	Excellent
Strong bases	Excellent
Salts	Excellent
Aliphatic Solutions	Good
Halogens	Good-Fair
Strong Oxidants	Good-Fair

CPVC is not recommended for use with chlorinated or aromatic hydrocarbons, esters, or polar solvents such as ketones.

NOT FOR USE WITH COMPRESSED AIR OR GASES

Spears Manufacturing Company DOES NOT RECOMMEND the use of thermoplastic piping products for systems to transport or store compressed air or gases, or the testing of thermoplastic piping systems with compressed air or gases in above and below ground locations. The use of our product in compressed air or gas systems automatically voids any warranty for such products, and its use against our recommendation is entirely the responsibility and liability of the installer.

WARNING: DO NOT USE COMPRESSED AIR OR GAS TO TEST ANY PVC OR CPVC THERMOPLASTIC PIPING PRODUCT OR SYSTEM, AND DO NOT USE DEVICES PROPELLED BY COMPRESSED AIR OR GAS TO CLEAR SYSTEMS. THESE PRACTICES MAY RESULT IN EXPLOSIVE FRAGMENTATION OF SYSTEM PIPING COMPONENTS CAUSING SERIOUS OR FATAL BODILY INJURY.



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4.2 Expansion Tank

The water heater safety tank is a specifically-designed pressure-absorbing device. It protects the entire plumbing system, including the water heater, from over-pressurization caused by thermal expansion. As water is heated, it expands, and since water is not compressible, a rapid increase of pressure in the water heater and throughout the entire plumbing system results. This increase in pressure is known as thermal expansion, occurring every time the water heater heats water and the expanded water is not allowed to return to the supply line.

The water heater safety tank operates as a collection point to accept thermally-expanded water. As water enters the tank, the diaphragm is pressed downward, compressing the captured air cushion in the tank. The air volume is specifically engineered to control pressure well below the water heater pressure relief valve setting. As water is used, the thermally expanded water is expelled from the tank back into the piping system by the compressed air cushion.

4.3 Thermal Expansion

Before the advent of cross connection control, expanded water that exceeded the capacity of the tank flowed back to the city main, where it was easily dissipated. It was 'open' at the city side of the supply system. Today, with back flow preventers, water meter check valves, and pressure-reducing valves without a bypass being installed, expanded water from a water heater cannot return to the city supply. It is now a '*closed system*,' and the expanding water has no place to go. Dangerous conditions exist during thermal expansion long before the relief valve operates. Internal pressures repeatedly occurring during recovery periods can 'stress' the tank, causing the tank welds and fitting connections to the tank to weaken. Remember:

water + heat + pressure + closed system = potential explosion

As a result, the expanding water creates a rapid and dangerous pressure increase in the water heater and system piping inside the residence. Eventually, the combination of temperature, pressure and the closed system will activate the T&P valve. The setting on the safety relief is quickly reached and the relief valve opens, losing heated water down the drain -- or all over the floor. Even though the relief valve operates during each recovery period, internal high pressures occurring over and over again can accelerate tank leakage and shorten water heater life. A good indication of thermal expansion is when the T&P valve releases about one cup of water for each 10 gallons of heater capacity with each heating cycle.

T&P valves are safety limit devices that will prevent or relieve overheated water and pressure. Without a relief valve during an unsafe condition, the tank pressure would rise to the point the tank may rupture or explode. This would cause potential damage to both people and property. Water heaters are pressure tested to 300 pounds per square inch (psi) and have a working pressure of 150 psi. The T&P valve is designed to open when the pressure inside the tank exceeds 150 psi. The T&P valve will also open if the water temperature reaches 210 F. The valve will continue to function, or remain open, until the unsafe condition is over.

4.3.1 Thermal Expansion Calculations

Calculate the expansion of 50 gallons of water with a temperature increase of 80 degrees F.

$$\Delta V = \beta V \Delta T$$

$$H_2O = \beta = .21 \times 10^{-3}/^{\circ}C$$

$$\Delta V = (.21 \times 10^{-3}/^{\circ}C) (50 \text{ gal}) (80^{\circ}F) \left(\frac{5^{\circ}C}{9^{\circ}F} \right)$$

$$\Delta V = .47 \text{ gal}$$

Calculate the volume of 1/2 inch CPVC pipe, ID (0.608 in.)



$$V = \pi r^2 h$$

$$V = \pi (.304 \text{ in.})^2 (1 \text{ ft}) \left(\frac{12 \text{ in.}}{1 \text{ ft}} \right)$$

$$V = 3.48 \text{ in}^3/\text{ft}$$

Calculate the distance the expanded volume of water will occupy in 1/2 CPVC.

$$(.47 \text{ gal}) \left(\frac{\text{in}^3}{4.3 \text{ E-3 gal}} \right) \left(\frac{\text{ft}}{3.48 \text{ in}^3} \right) = 31.4 \text{ ft for } .5 \text{ in.}$$

Calculate the volume of 3/4 inch CPVC pipe, ID (0.810 in.)

$$V = \pi r^2 h$$

$$V = \pi \left(\frac{.810}{2} \right)_{\text{in}}^2 12 \text{ in}$$

$$V = 6.18 \text{ in}^3/\text{ft}$$

Calculate the distance the expanded volume of water will occupy in 3/4 inch CPVC.

$$(.47 \text{ gal}) \left(\frac{\text{in}^3}{4.3 \text{ E-3 gal}} \right) \left(\frac{\text{ft}}{6.18 \text{ in}^3} \right) = 17.7 \text{ ft for } 3/4 \text{ in.}$$

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