2005 WJTA American Waterjet Conference
August 21-23, 2005 • Houston, Texas

Paper

SAFE WATERJET CLEANING OF SEWER PIPE

D. Wright, J. Wolgamott, G. Zink
StoneAge, Inc.
Durango, Colorado, U.S.A.

ABSTRACT

Sewer lines are commonly cleaned using waterjet systems with pressures up to 70 Mpa (10,000 psi). There is a risk of damaging these lines depending on operating parameters and pipe material. Sewer and drain line systems can be composed of vitrified clay, PVC, cast iron, or concrete. Vitrified clay pipe has been in use for sewer and storm drains since before 1900. PVC plastic pipe came into widespread use in the late 1960's and early 1970's, and is being used for many current installations. Other materials such as fiberglass/epoxy resins and HDPE are being used in rehabilitation of old lines. The purpose of these tests was to determine waterjet operating parameters below which no damage would be caused to vitrified clay pipe or PVC pipe, the two most common materials, as well as HDPE, a material used for slip lining of existing pipes.

Organized and Sponsored by the WaterJet Technology Association

1. INTRODUCTION

These tests were conducted to determine safe operating parameters to prevent damage to sewer and drain pipe materials. Variables such as rotation, jet angle, and time affect the minimum pressure that will damage these materials.

Waterjet cleaning of sewer and drain piping is most commonly performed at operating pressures between 10.5 and 28 MPa (1500 and 4000 psi), with flow rates varying from 30 to 300 lpm (8 to 80 gpm). Typical sewer jetting arrangements have hose lengths that result in pressure losses of 2 to 10.5 MPa (300 to 1500 psi), meaning that the pressure at the nozzle is 2 to 10.5 MPa (300 to 1500 psi) less than the pressure shown on the gage at the pump. All pressures reported in these tests are pressures at the nozzle.

2. TESTING

Two basic types of tests were performed, one set with a stationary jet and the other with rotating jets. For the stationary jet testing, a single nozzle with flow straightener, 1.6 mm (.063 in.) diameter was mounted at 135 degrees to the pipe surface with a 25.4 mm (1 in.) standoff distance. For the rotating jet tests, a self-rotating swivel was mounted within an inch of the inner pipe surface, illustrated in Figure 1. Rotation speeds varied from 150 to 300 rpm. Two nozzles with flow straighteners, 1.6 mm (.063 in.) diameter, were used in these tests. Ports in the head provided jet angles of 90, 135 and 150 degrees, illustrated in Figure 2. The rotating jets were left in the same location for time periods of 10, 30, 60 and 120 seconds. One section of new 200 mm (8 in.) clay pipe was cut into quarters and used for all of the clay pipe tests except the comparison of three additional samples. One section of new 200 mm (8 in.) PVC pipe was used for all of the PVC tests.

The damage caused by the rotating jets was measured in terms of volume of material removed. This produces a value that can be expressed on a chart to show a relative comparison between tests and rates of increase. Figures 3 and 4 show a vitrified clay pipe sample and a PVC pipe sample used for the tests.

3. RESULTS

3.1 Stationary Jet Minimum Pressures

3.1.1 Vitrified Clay Pipe

The static jet tests in the vitrified clay pipe resulted in slightly better minimum pressure results than the rotary jet tests. The minimum pressure to damage the pipe was dependent on local weaknesses; the rotating jets had a better chance of finding weak spots because they covered more area. The stationary jet at a pressure of 17.5 MPa (2500 psi) produced no damage after 120 seconds, while 21 MPa (3000 psi) began to damage the material after exposure beyond 60 seconds.

3.1.2 PVC Pipe

The static jet tests conducted in PVC pipe produced a much lower minimum pressure result than the rotary jet tests. The static jet was placed at the 135 degree position in the head. A pressure of 14 MPa (2000 psi) produced a small hole when left in the same location for 10 seconds; when the pressure was reduced to 10.5 MPa (1500 psi) no damage was present after 120 seconds.

3.2 Effect of Pressure and Angle with Rotary Jets

3.2.1 Vitrified Clay Pipe

A series of rotary jet tests were conducted to determine the effect of jet angle on the maximum safe pressure in new vitrified clay pipe. Each of these tests was run for 10 seconds, after which the samples were measured for volume of material removed. Results are shown in Figure 5. The 90 degree and 135 degree jets both began removing slight amounts of material at 24.5 MPa (3500 psi), but as pressure was increased, the amount of damage caused by the 90 degree jets grew at a much higher rate than that of the 135 degree jets. The 150 degree jets began to damage the pipe at 49 MPa (7000 psi), with a still lower rate of increase with increasing pressure. These tests show that reducing the angle of impingement can allow higher operating pressures without damage to the vitrified clay pipe.

Three other samples of vitrified clay pipe were tested using the 90 degree rotating jets for 10 seconds. These samples came from different sections of a storm drain line that had been in place for over 50 years. They were in relatively good condition, however. The results are shown in Figure 6; two of the three pieces had the same minimum pressure as the primary test sample material that had never been used. There possibly exist clay pipe installations, particularly in sanitary sewers where the pipe has been submerged for many years, where the material has degraded to a softer condition and might be more susceptible to jet damage.

3.2.2 PVC Pipe

These rotary jet tests were conducted on PVC pipe to determine the effect of jet angle on the maximum safe pressure. Each of these tests was run for 10 seconds, after which the samples were measured for volume of material removed. Results are shown in Figure 7. The 90 degree and 135 degree jets both began removing material at 49 MPa (7000 psi), while the 150 degree jets first created damage at 73.5 MPa (10,500 psi). All three conditions increased at nearly equal rates once the minimum pressure to create damage was reached. Just as in the vitrified clay pipe, a reduced angle of impingement allows higher operating pressures without damage to the PVC material.

3.2.3 HDPE Pipe

The HDPE pipe did not respond in the same manner as the other two materials, likely because the HDPE material is more plastic in behavior and a little bit softer than the PVC material. The minimum pressure for initial damage for jet angles of 90 to 150 degrees occurred at the same pressure of 49 MPa (7000 psi), although the amount of material removed increased at a greater rate with increasing pressure with the 90 degree jets. Figure 8 illustrates this data.

3.3 Time of Exposure with Rotary Jets

These tests were conducted to determine if pressures below the values determined in the previous tests would create damage if the jets were left rotating in the same place for long periods of time. The results show that if higher operating pressures are used, the tool should be kept moving through the line to avoid damage. However, if the tool will be deliberately or accidentally left in place for an extended period of time, lower operating pressures should be used.

3.3.1 Vitrified Clay Pipe

Material removal in the vitrified clay pipe at pressures less than the 10 second maximum values occurred by exploitation of tiny pits in the material, which would grow with each successive pass of the jets. The 90 degree jets produced damage at 17.5 MPa (2500 psi) when left in place for longer than 60 seconds, while 21 MPa (3000 psi) resulted in damage after 30 seconds. These results are shown in Figure 9. Figure 10 shows results for the 135 degree jets, which did not produce any damage at 17.5 MPa (2500 psi) after 120 seconds, while 21 MPa (3000 psi) resulted in damage after 30 seconds. The 150 degree jets were tested at 28 MPa (4000 psi) with essentially no damage after 120 seconds, while 35 MPa (5000 psi) resulted in damage after 30 seconds and rapidly increasing damage thereafter; these results are shown in Figure 11. Figure 12 shows the increasing rate of material removal by the 90 degree jets compared to the 135 degree jets. Both created damage at the same pressure, but when compared after 120 seconds, the damage caused by the 90 degree jets was 10 times as great.

3.3.2 PVC Pipe

The mechanism by which PVC pipe was damaged over time at lower pressures was probably due to fatigue of the material, quite different than the vitrified clay pipe. No material removal would occur up to a point in time, and then suddenly a groove would appear and grow. Spalling of the material from the groove occurred once the cut depth resulted in confinement of the jet.

Figure 13 shows the results for PVC with the 90 degree jets, where 42 MPa (6000 psi) did not remove any material up to 30 seconds, but did after exposure for longer time periods. While 90 degree jets at 49 MPa (7000 psi) for 10 seconds or less produced no damage, a pressure of 42 MPa (6000 psi) or less would be required for extended periods of exposure. Material removal occurred at the same pressures and time periods with the 135 degree jets, as shown in Figure 14, but Figure 15 illustrates the relative magnitude of damage done by the 90 degree jets compared to that caused by the 135 degree jets. Figure 16 shows that it would be possible to operate up to 66.5 MPa (9500 psi) with 150 degree jets if exposure did not exceed 30 seconds.

3.3.3 HDPE Pipe

The HDPE material did not show much difference between the 10 second maximum pressure and pressures that would damage it over time; this was likely due to the greater plasticity of the material compared to the clay and PVC. 49 MPa (7000 psi) did not damage the material over a 30 second time period, and produced only slight damage after 120 seconds.

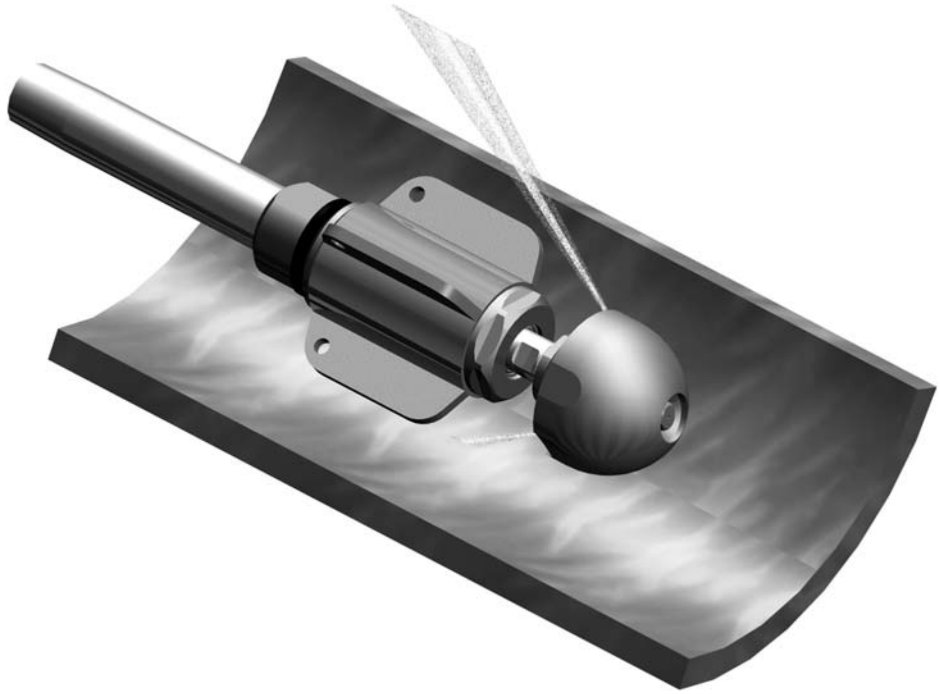
4.0 CONCLUSIONS

Tests were conducted in vitrified clay pipe, PVC pipe and HDPE pipe to determine safe operating parameters for waterjet cleaning without damage to the pipe material. The minimum safe operating pressure typically occurs with a non-rotating, non-moving (static) jet. Rotating the jets increases this minimum pressure, as will reducing the angle of impingement of the jet on the pipe wall. However, longer time spent on one area will tend to exploit weaker portions of the material or create fatigue, reducing the maximum safe operating pressure to prevent damage to the pipe. Through the use of a rotating nozzle head, reducing the angle of the jets and keeping the tool moving down the line, pressures at the nozzles may approach 49 to 70 MPa (7000 to 10,000 psi) without damage to the pipe. However, if the tool will be deliberately or accidentally left in place for an extended period of time, lower operating pressures should be used.

For vitrified clay pipe, the maximum safe nozzle pressure with an exposure time of 120 seconds with rotating 90 degree jets was found to be 17.5 MPa (2500 psi). However, if the exposure time was kept at 10 seconds or less and a jet angle of 150 degrees was used, operating pressures up to 42 MPa (6000 psi) could be used.

Maximum nozzle pressures for PVC pipe vary from 10.5 MPa (1500 psi) for a stationary jet to 38.5 MPa (5500 psi) for the 120 second exposure time with 90 degree rotating jets, to as high as 70 MPa (10,000 psi) with rotating jets, exposure times less than 10 seconds and a jet angle of 150 degrees.

The HDPE pipe did not have as wide of a range dependent on exposure time and jet angle; the safe nozzle pressures varied from 45.5 to 49 MPa (6500 to 7000 psi).



Rotary Nozzle and Quarter Section of Pipe as Tested
Figure 1.

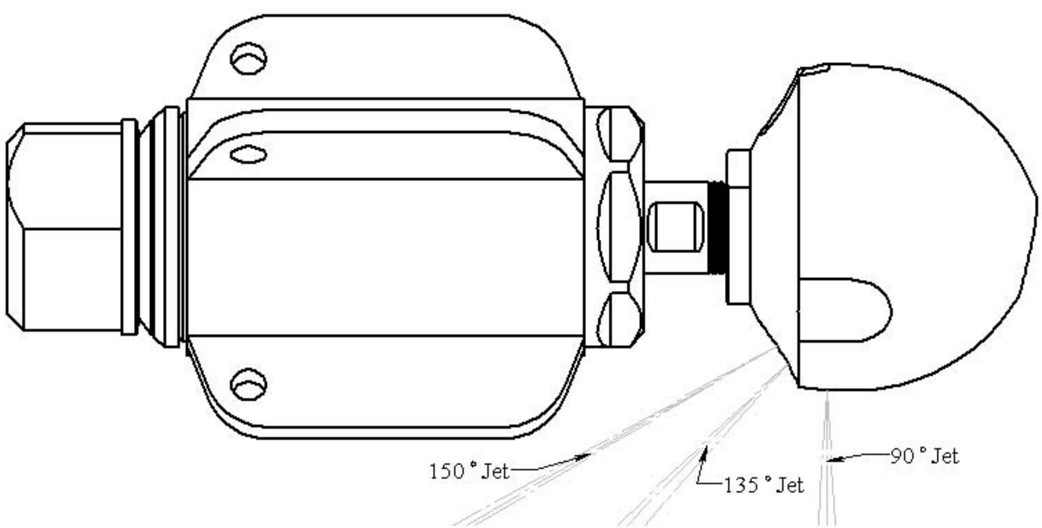
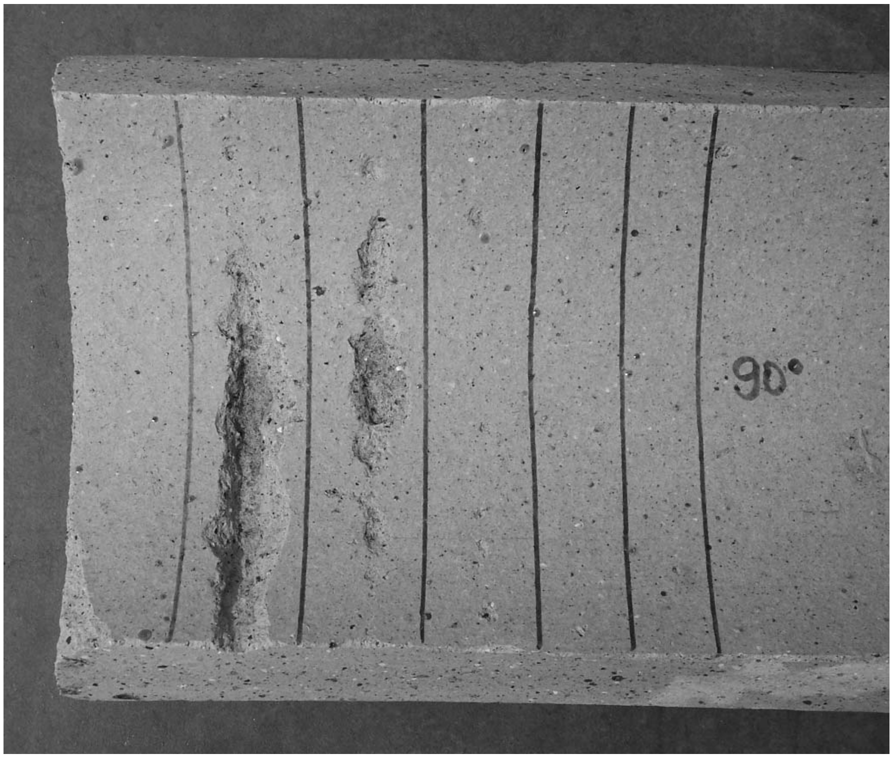
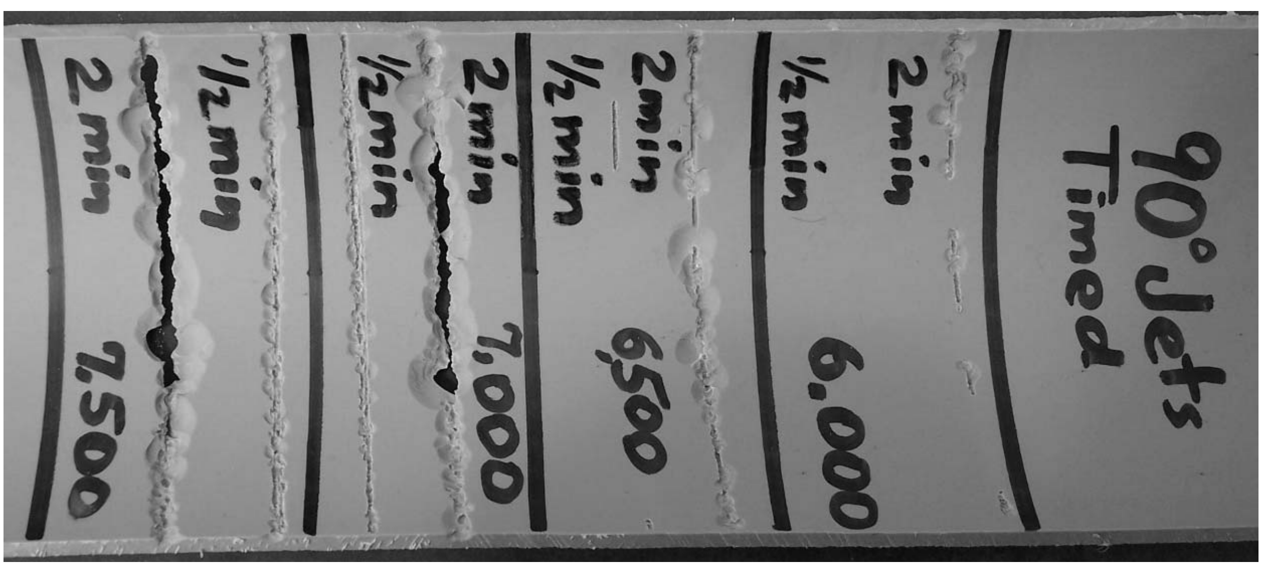


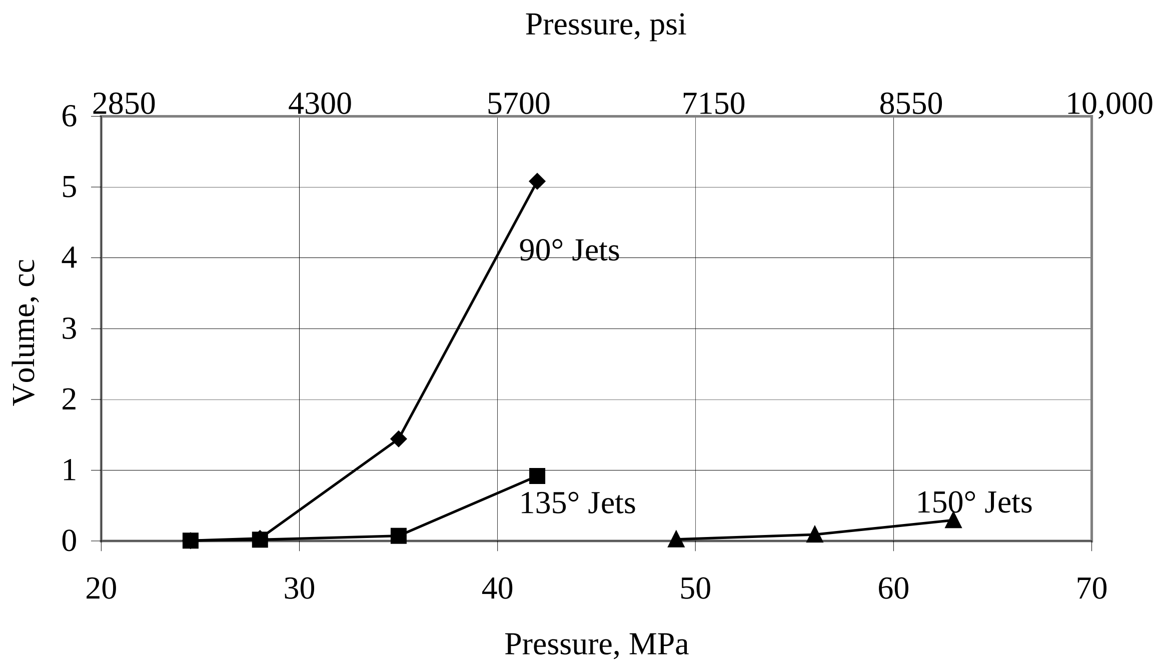
Illustration of Jet Angles
Figure 2.



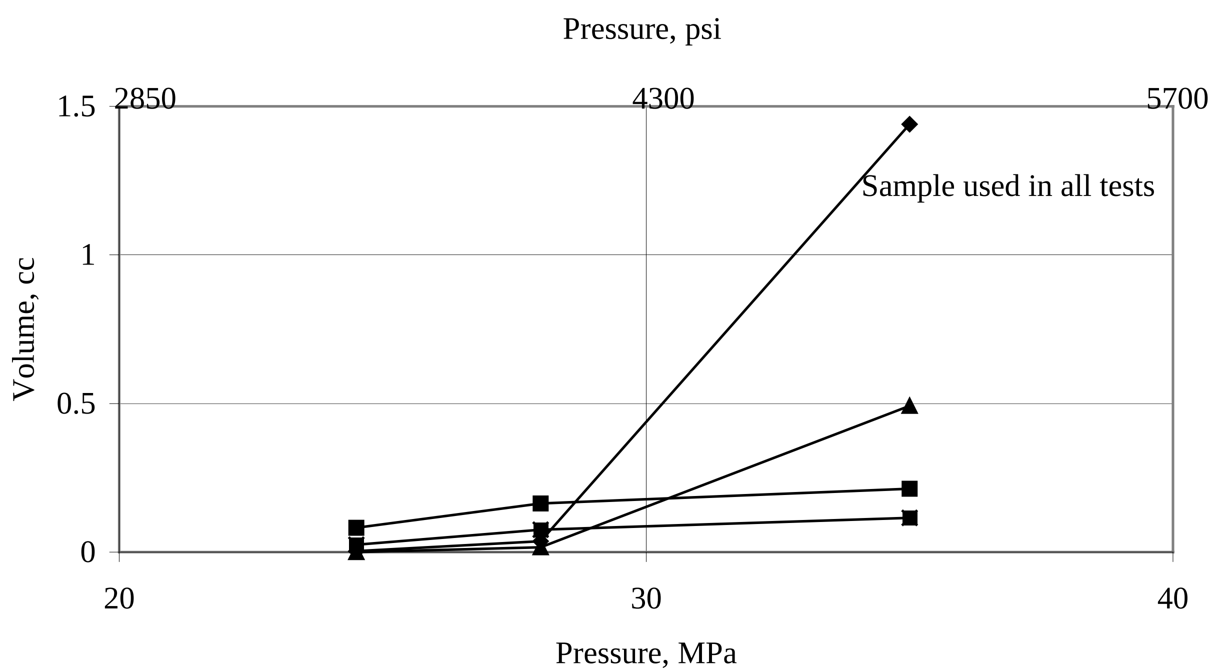
Vitrified Clay Pipe
Figure 3.



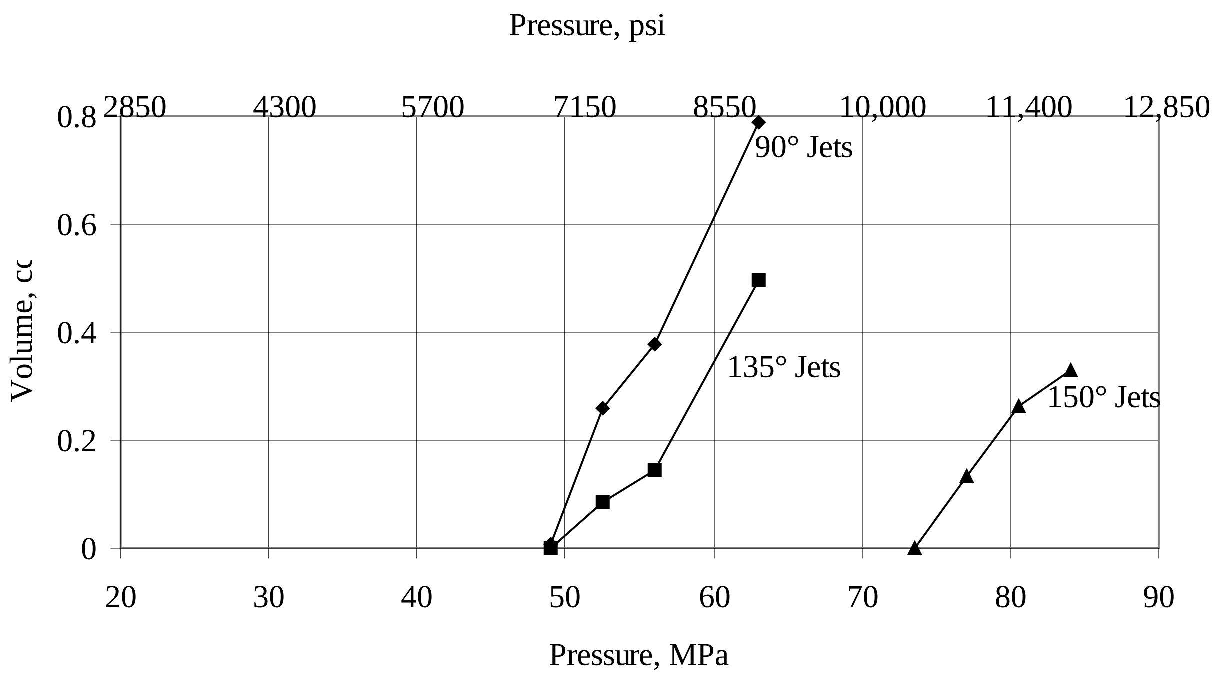
PVC Plastic Pipe
Figure 4.



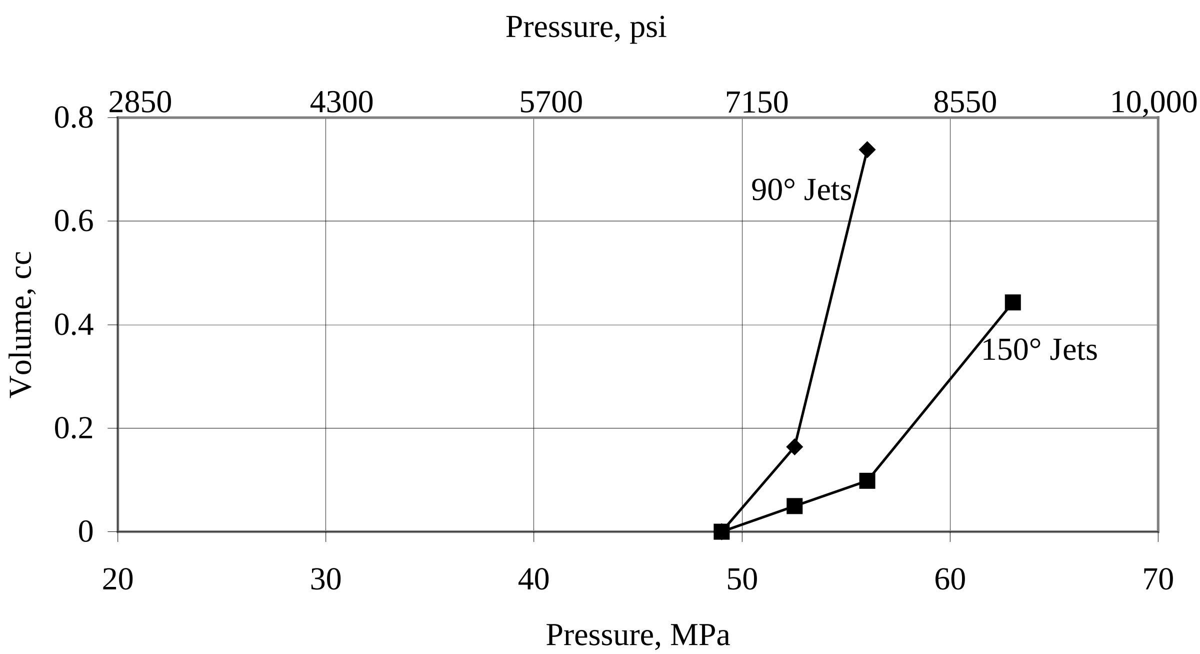
Effect of Pressure and Jet Angle on Vitrified Clay Pipe
Figure 5.



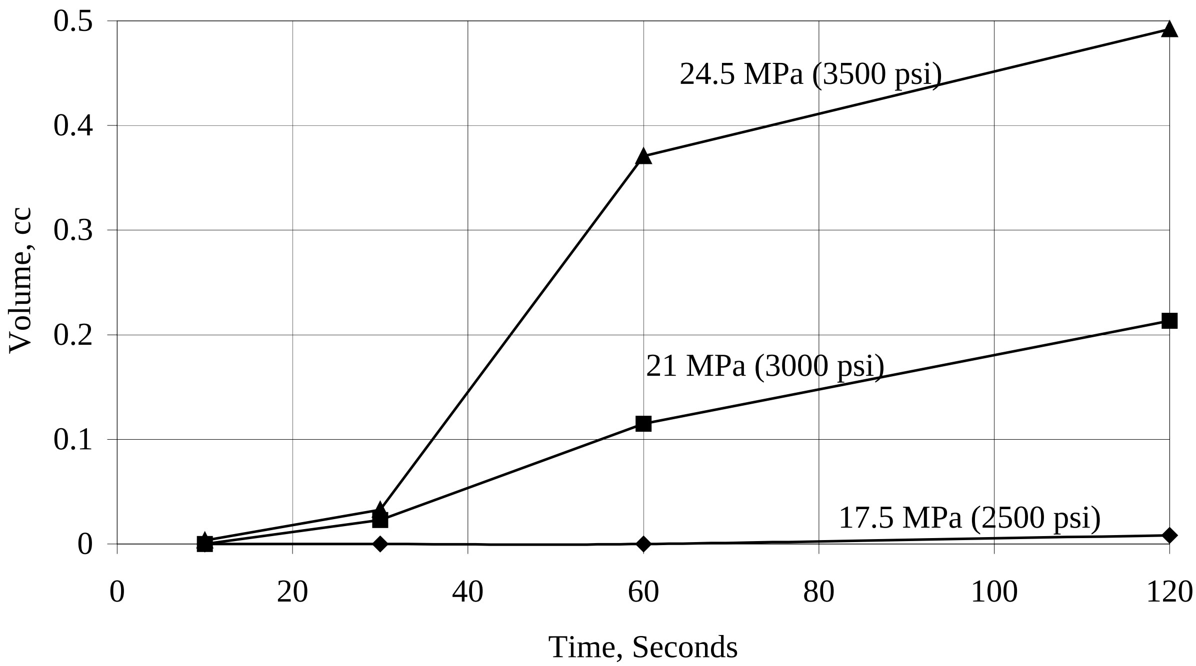
Comparison of Four Vitrified Clay Pipe Samples, with 90° Jets for 10 Seconds
Figure 6.



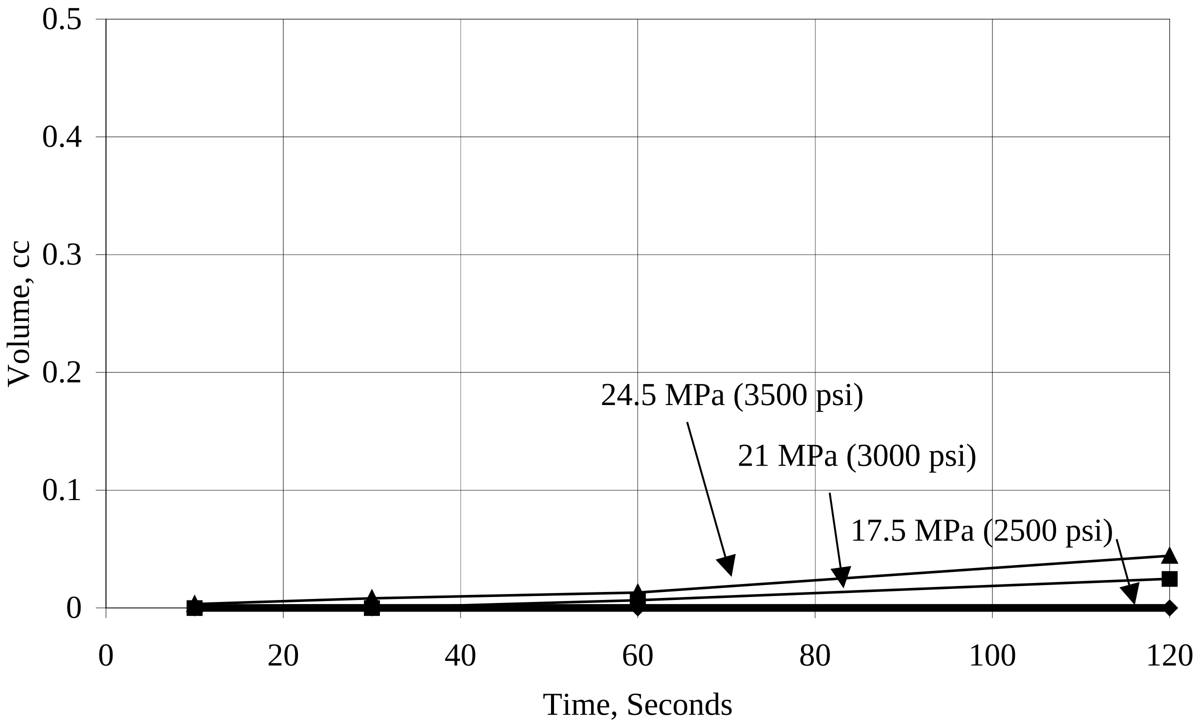
Effect of Pressure and Jet Angle on PVC Pipe
Figure 7.



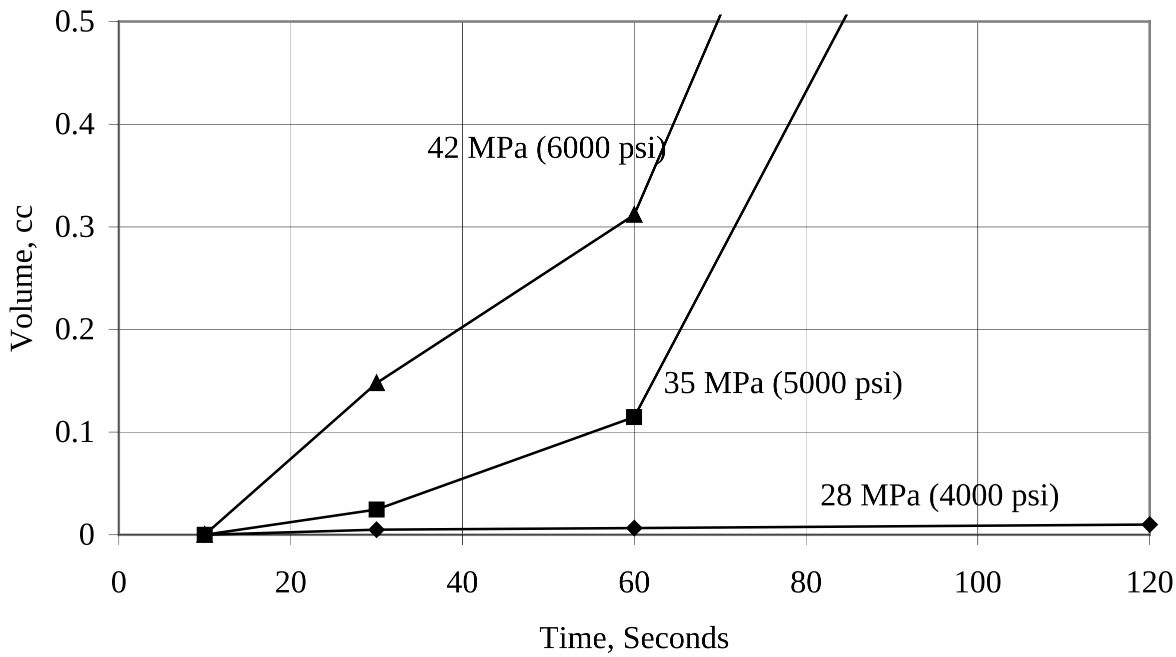
Effect of Pressure and Jet Angle on HDPE Pipe
Figure 8.



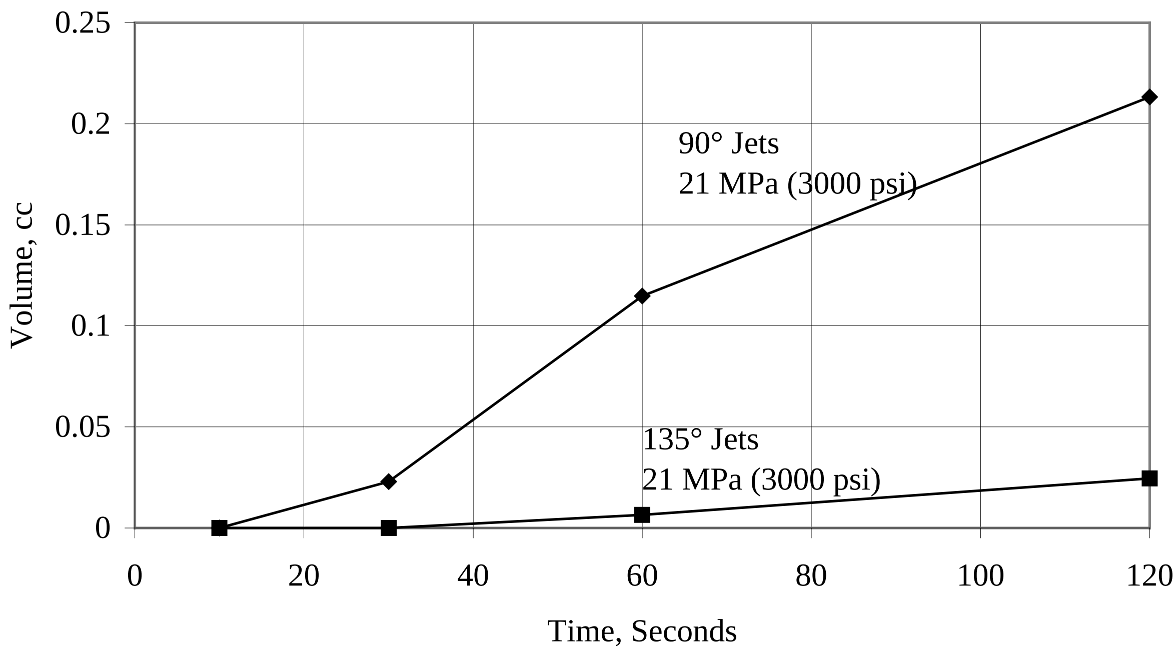
Effect of Time and Pressure with 90 Degree Jets on Vitrified Clay Pipe
Figure 9.



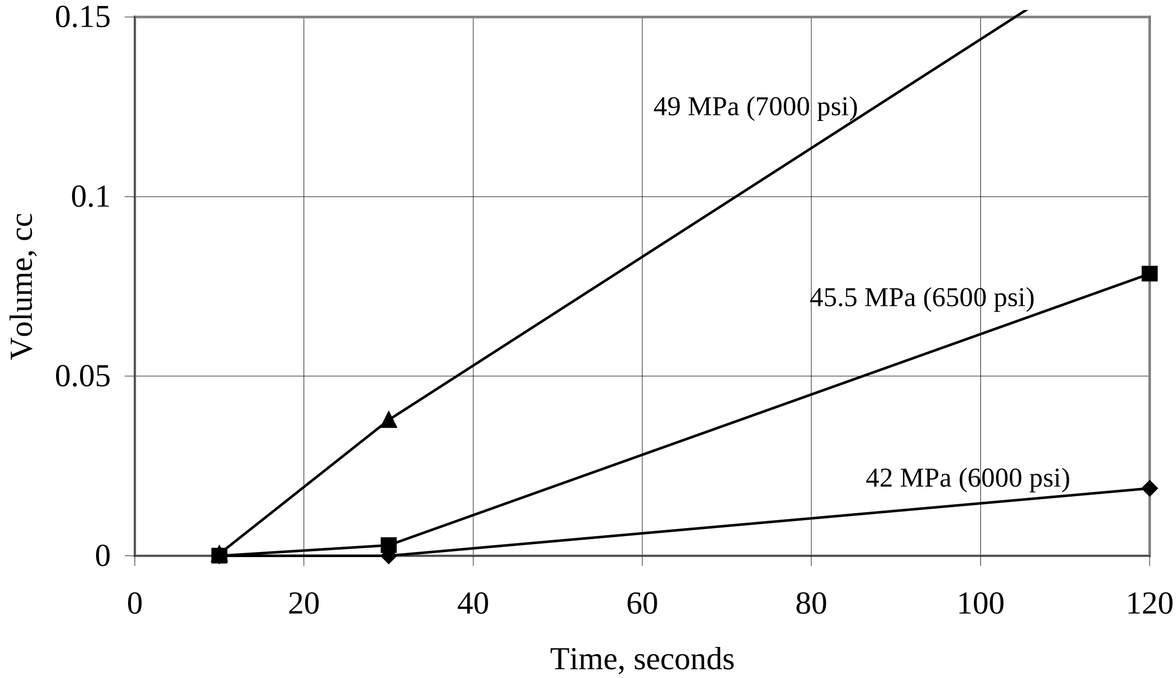
Effect of Time and Pressure with 135 Degree Jets on Vitrified Clay Pipe
Figure 10.



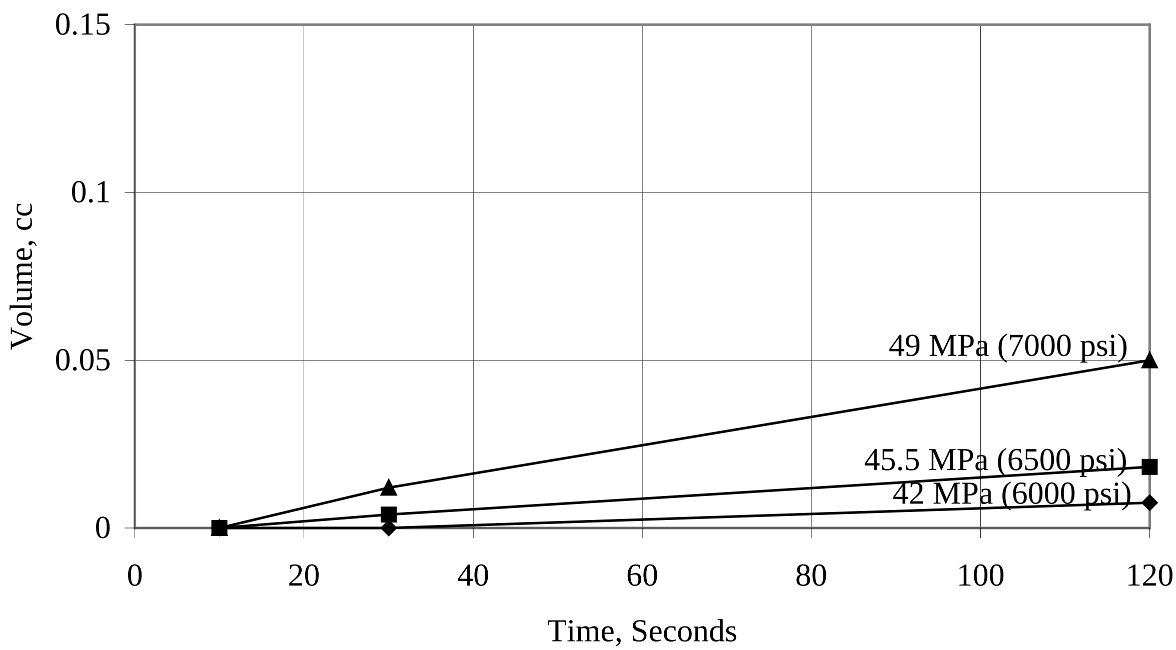
Effect of Time and Pressure with 150 Degree Jets on Vitrified Clay Pipe
Figure 11.



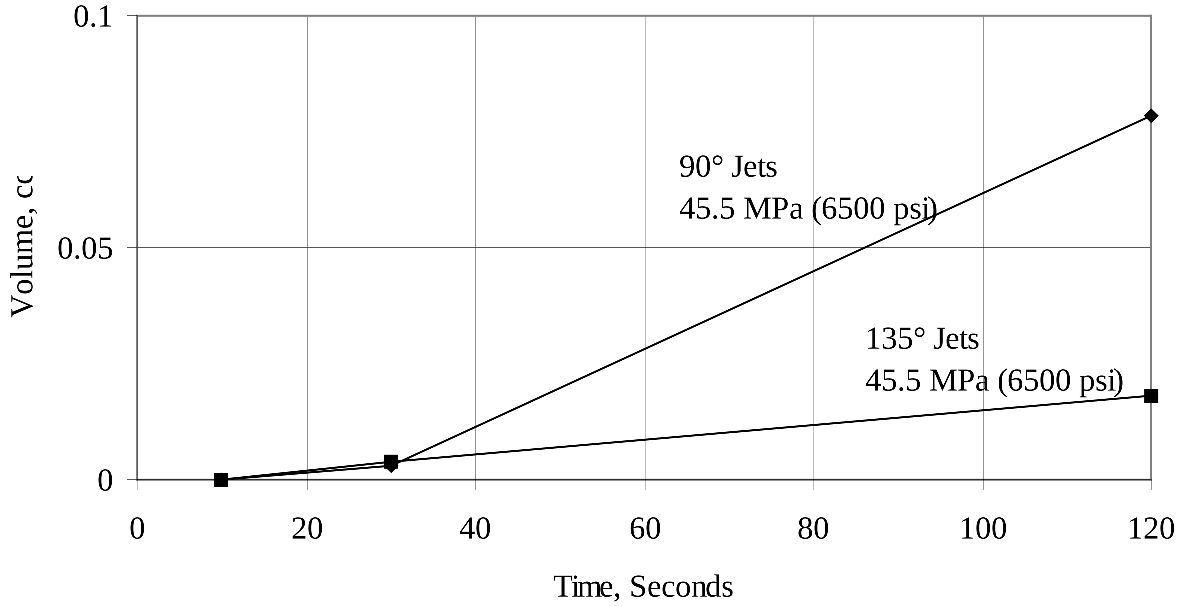
Effect of Angle and Time on Vitrified Clay Pipe
Figure 12.



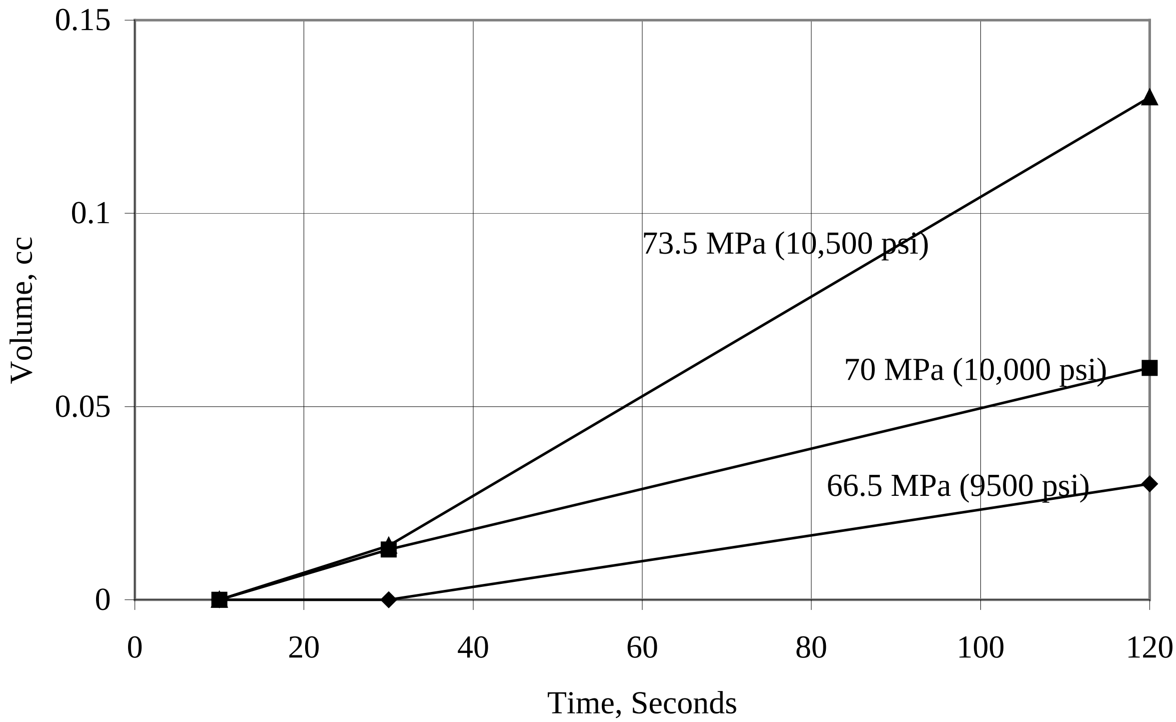
Effect of Time and Pressure with 90 Degree Jets on PVC Pipe
Figure 13.



Effect of Time and Pressure with 135 Degree Jets on PVC Pipe
Figure 14.



Effect of Angle and Time on PVC Pipe
Figure 15.



Effect of Pressure and Time with 150 Degree Jets on PVC Pipe
Figure 16.