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PENETRATION OF FIRE SEPARATIONS BY PLASTIC PIPE

(2nd Progress Report)

by

P.C. Attwood

PREFACE

The SPI-NRC fire research fellowship program is a joint undertaking of the Society of the Plastics Industry of Canada and the National Research Council of Canada. Its objective is to determine whether plastic pipe can be used safely in high-rise buildings. The fellowship is administered by a steering committee who meet approximately every six months.

This progress report is based on information included in a previous report presented to the steering committee in September 1978; it covers the period from February to August 1978. The material included herein is, therefore, a continuation of that contained in the first progress report.(1)

Ottawa
June 1979

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Director, DBR/NRC

NATIONAL RESEARCH COUNCIL OF CANADA

DIVISION OF BUILDING RESEARCH

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PENETRATION OF FIRE SEPARATIONS BY PLASTIC PIPE
(2nd Progress Report)

by P.C. Attwood

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The objective of this program is to determine the behaviour of plastic piping when exposed to positive pressure fire conditions, and to determine how this behaviour could be altered or utilized by various construction assemblies.

Because drain, waste and vent (DWV) pipe represents the most difficult application of plastic pipe in high-rise buildings, it is the primary area of study for this program. Information derived from solutions to the DWV pipe problem should be readily adaptable to other uses for plastic piping.

The first progress report explored the problem of horizontal penetrations of vertical fire separations. This report studies that problem further and extends into the area of vertical penetrations of horizontal fire separations.

All work in this program completed to date has utilized small-scale fire resistant furnaces. Data obtained from this segment of the program is presented herein. A summary of the test assemblies and results is included in Tables 1 to 4; a complete description of the tests is given in Sections A and B.

The distinctive feature of this program, compared with other research programs involving plastic pipe, lies in the fact that all tests were conducted at a positive pressure of 0.2 in. of water. The adoption of this condition was based on work by Tamura (2) which shows that pressure differentials of this magnitude can exist in high-rise structures during the winter months.

It was assumed for this program that both horizontal penetrations and vertical penetrations must maintain their integrity independently under fire conditions. Consequently, each penetration is treated separately. The alternative to this approach is to assume that fire in a vertical shaft will most probably originate in a compartment, and hence must propagate from the compartment to the shaft. In that case, a test assembly allowing for sequential penetrations, horizontal and then vertical, would be representative.

The first report in this program(1) described a series of tests designed to investigate the behaviour of horizontal plastic pipe when exposed to fire. This present report contains the results of the remainder of that series, and also presents the results obtained from the first tests in a series of vertical pipe assemblies.

The following section presents a brief summary of test assemblies and results with a minimum of explanation. A description of the test facilities is given in Section A; a full discussion of test assemblies and observations is given in Section B.

TEST ASSEMBLIES AND RESULTS

All tests involving plastic pipe have used either polyvinyl chloride (PVC) or acrylonitrile-butadiene-styrene (ABS) drain, waste and vent (DWV) pipe, and, with two exceptions, represent simple vented plumbing assemblies. The tests have all been conducted at a positive furnace pressure of 0.2 in. of water and have followed the time-temperature curve stipulated in ASTM E119 and ULC S101 standards.

a) Horizontal Tests

Table 1 presents a summary of test assembly construction features, along with the duration time of the test and any pertinent remarks.

In general, each wall assembly consisted of two layers of 5/8 in. Type X gypsum wallboard backed by a sheet of 16-gauge steel, through which the horizontal portion of the plumbing assembly passed. The exposed end of the plumbing assembly was capped, giving the same effect as a P-trap, and the unexposed side consisted of either an open pipe or a fitting and a vertical stack. The dimensions of the horizontal pipes are given in the "Pipe Size and Material" column of Table 1. Where a second dimension is given, a stack of that diameter was used in the assembly.

The definition of failure used in these horizontal tests was any condition that allowed flame to propagate from the furnace to the unexposed side of the wall, or any condition that allowed hot gases to escape from the closed system created by the furnace and the plumbing assembly.

Three series of tests were run using plastic pipe; a single test was conducted using copper pipe. In continuing series No. 4 simple mechanical devices designed to determine whether a simple seal could be created and serve as a barrier to flame propagation and gas flow were studied. In test series No. 5 a simple guillotine attached to a box filled with an insulant was used, and in series No. 6 the effectiveness of a double mechanical seal was studied. The test in series No. 7 was designed to provide comparative information regarding heat conduction.

A summary of the results of these tests follows.

1. A simple mechanical device mounted on the end of a sleeve provided some protection but did not establish a complete seal. The great disparity in the results of tests Nos. 4 and 5 seems due more to the pipe material than to the nature of the mechanism. The intumescent nature of PVC combined with the corrosive effect of the products of combustion of PVC delayed failure of this test substantially.

2. A simple guillotine mounted on the front of a box combined with the insulating ability of sand to provide two-hour protection in four tests using both ABS and PVC pipe. The mechanism involved was a combination of the insulating effect demonstrated in the sand trough experiments and the physical barrier described in the foregoing paragraph. A single test using gypsum powder as the insulant failed after 31 minutes as the gypsum formed a calcite and failed to fall into the open space as the ABS pipe disintegrated.

3. Eight tests were run using both 1 1/2- and 3-in. assemblies of ABS and PVC pipe in conjunction with a double flapper device. All tests ran for two hours without failure.

b) <u>Vertical Tests</u>

The furnace used for testing vertical plumbing assemblies is described fully in Appendix A. The top of the furnace is formed by a 4-in. thick reinforced concrete slab, through which the pipe assembly passed, representing vertical plumbing penetrating a fire separation. Again, the exposed end of the piping was capped and the unexposed end left open, as would be the case if fire should start outside a vented plumbing assembly. For non-vented plumbing assembly tests, both ends of the pipe were capped.

Table 2 presents a summary of test assembly construction features, the duration time of the test, and some pertinent remarks. In series "B", tests Nos. 2 and 3 were designed to demonstrate how vertical ABS and PVC burn. Each pipe was protected by a 12-in. long sleeve. Tests Nos. 4 and 5 added gravity activated flappers to each end of the sleeve to study the effect of a physical barrier on fire propagation. Tests Nos. 6, 7 and 8 were designed to study the effect of a pipe passing through a small cavity between the exposed area and the unexposed area. The pipe, 2 in. in diameter, entered the cavity at a 45^o angle and was sleeved on both sides of the cavity.

In series "C", two tests were run using 2-in. non-vented assemblies. In each test, one in PVC, the other in ABS, two sections of pipe penetrated the concrete slab with different length sleeves.

A summary of the significant results of these tests follows.

1. Unprotected vertical pipe, or pipe protected only by a steel sleeve allowed fire to propagate beyond the fire separation in a relatively short time, i.e., 15 min. for ABS and 37 min. for PVC.

2. The flapper assembly successfully prevented propagation of fire for 2 hours with PVC pipe, but failed after 37 minutes with ABS, primarily because the sleeve was not properly mounted. The tests also revealed some problems associated with the materials used in constructing such an apparatus.

3. The use of a cavity below the fire separation delayed failure until 76 min. for PVC and 40 min for ABS. The principal reasons for this are two-fold: the 45^o sleeve allows a temporary seal to form in the sleeve as the pipe softens, and the air in the cavity acts as an insulant until its temperature reaches that of the furnace.

4. Unvented small diameter pipe systems will not propagate fire vertically as long as the pipe is sleeved through and above the fire separation.

Conclusions

1. A double mechanical seal created by a device such as the one described in horizontal series No. 6 will prevent fire propagation by the pipe for at least 2 hours. This is applicable to both ABS and PVC pipe.

2. A similar device in the vertical mode, as shown in test No. B-3 will prevent fire propagation vertically by PVC pipe. A demonstration for ABS is yet to be done.

3. Fire propagation through a horizontal fire separation can be retarded for more than one hour for 3-in. PVC by utilizing a construction technique that calls for a 45° offset in the pipe to occur at the wall of a cavity below the separation.

4. Non-vented small diameter pipe (1 1/2 and 2 in.) will not propagate fire past a horizontal fire separation for at least two hours as long as a sleeve of sufficient length is used for protection.

SECTION A

TEST FACILITIES

The furnace used for assemblies representing horizontal pipe was fully described in the previous interim report(1). It consists of a rectangular outer shell with eight burners, and an inner cylindrical chamber that provides the exposure area. The flue is located in the bottom of the inner chamber, and combustion air is supplied through a forced air system resulting in a positive pressure within the furnace. With this furnace construction, the test specimen is not exposed to direct flame.

The furnace used for vertical pipe assemblies consists of an open top rectangular shell having four large burners. The open top of the furnace is covered with a 4-in. reinforced concrete slab, through which the vertical pipe assemblies pass. The slab has a 1-in. protective layer of Fiberfrax* on the bottom to prolong its life. The forced air supply creates a positive pressure inside the furnace, and the flue, located in the bottom of the furnace, is equipped with a manually operated damper for pressure control. Unlike the horizontal furnace with its double chamber design, this furnace is a single chamber design (Figure 1)

SECTION B

DISCUSSION OF TEST ASSEMBLIES AND RESULTS

HORIZONTAL TESTS

Table 3 presents a tabular summary of all test assemblies and results. Significant construction details are included in the assembly description.

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* "Fiberfrax" is a registered trade name for a ceramic fiber material produced by the Carborundum Company.

Throughout this series of tests, the wall structure used consisted simply of two sheets of 5/8-in. Type X gypsum wall board backed with a sheet of metal. The metal sheet was used to protect against wall failure.

a) Series No. 4

This series of tests investigated simple mechanical devices designed to create a seal against the flow of hot gases from a fire-involved compartment to an adjacent compartment. The first three tests in this series were reported in the first progress report(1).

The simple flapper used in test No. 4, the guillotine in test No. 5 and all subsequent assemblies that form a simple barrier were designed to take advantage of the fact that all thermoplastics soften at temperatures substantially lower than their ignition temperatures. The softening of the pipes allowed these simple devices to close under the influence of gravity.

The flapper device used in test No. 4 (see Figure 2) failed in 30 minutes with ABS pipe. The sleeved part of the device had been insulated, as had the flapper itself to reduce heat conduction and radiation. An imperfect seal between the flapper and the sleeve allowed hot gases to eventually leak through the device, however.

A similar situation existed with the simple guillotine device used in test No. 5 (see Figure 3). In this test, the assembly seemed stable until failure occurred abruptly at 1 hr 55 min. The considerably longer resistance of this assembly was attributed to two characteristics of PVC, those being the formation of a carboniferous char and the blistering of the metal components caused by the acidic products of combustion from PVC. The intumescent nature of PVC along with the formation of an ash plug protected the unexposed side of the assembly from any hot gas leaks. Continued exposure of the ash to heat causes the plug to become brittle and porous; by this time, however, the metal surfaces had blistered and sealed all openings. A leak eventually caused the pipe to ignite on the unexposed side of the structure. Examination of the assembly after the tests showed that the guillotine blade had warped because of the weight attached to it, causing an opening to develop at the top. In constructing this assembly care had been taken to ensure that while the blade channels allowed free movement of the guillotine, it was not loose. This construction constraint was applied to all mechanical devices used in this program.

b) Series No. 5

There were six tests run in this series, which was designed to combine the advantages of an insulating material with a simple guillotine structure. The assembly consisted of a box 5 in. deep, 10 in. high and 8 in. wide with the guillotine mounted on the front face (Figure 4). One and one half in. diameter ABS and PVC pipe was used throughout this series, and in each case the pipe had a 3-in. long steel sleeve located at the wall penetration. Guillotine weight varied from 1030 gm. to 1460 gm.

Five tests were run using sand as the insulating material and all tests ran for two hours without reaching failure, with the exception of one test that was terminated after ten minutes because of furnace malfunction. In all cases the mechanism was similar. Once the pipe had softened, the guillotine closed. Further destruction of the pipe within the box resulted in the sand filling the void created by the pipe. The only distinction between PVC and ABS behaviour lay in the fact that the carboniferous ash left by PVC seemed to delay the collapse of the sand above the pipe. In one test, the ash delayed the closing of the guillotine and thus allowed some sand to escape through the front of the box. The guillotine closed soon enough, however, that sufficient sand remained to cover the pipe.

The sixth test in the series used gypsum powder as an insulant. In this case, however, the heat caused the gypsum to form a calcite preventing the powder from filling the void, and the effect was that of creating an insulated sleeve. The ABS had been consumed to the end of the sleeve when the test was terminated after 31 minutes.

c) Series No. 6

This series was designed to study a double flapper mechanism. The device shown in Figure 5 consists of a 4-in. long steel sleeve with a flapper mounted at each end. Five of the eight tests included a Fiberfrax lining on the inside of the sleeve. All tests ran for the full two hour period. This device was based on a design patended by J. Blumenkranz[3].

The process whereby this double flapper device forms a seal was essentially the same in all tests, with slight differences occurring between ABS and PVC pipe. The stepwise process was as follows:

1. The increasing furnace temperature on the exposed side caused the pipe on the exposed side of the wall to soften, thus allowing the first swivel flapper to close and form an initial seal.

2. The temperature within the sleeve increased due to heat conduction and radiation. At the elevated temperature, the plastic pipe within the sleeve softened and allowed the flapper on the unexposed end to start to close.

3. Smoke and fumes from the disintegration of pipe within the sleeve vented through the attached plumbing stack.

4. Eventually, the plastic at the unexposed end of the sleeve softened sufficiently to allow the flapper at that end to close.

5. Once the unexposed flapper closed, the smoke and fumes from material in the sleeve could no longer vent through the plumbing system. At the same time flames appeared around the edge of the flapper on the exposed side, suggesting that the pressure in the sleeve exceeded the furnace pressure of 0.2 in. H_2O and that the combustible gases from the material in the sleeve were now escaping into the furnace.

6. After all flammable material in the sleeve was consumed the pressure in the furnace held the exposed flapper against the end of the sleeve thus maintaining the seal.

An important feature of this mechanism lies in the fact that it would work regardless of which side of the partition was exposed to fire. Figure 6 shows photographs of the unexposed flapper progression in test No. 7.

Figures 7(a), (b), and (c) graphically present thermocouple data from the inside of the tee, the unexposed side of the assembly, and the exterior surface of the tee, respectively. In each Figure the upper graph represents PVC assemblies and the lower graph ABS assemblies. The differences between the ABS and PVC graphs are probably due to the differences in the behaviour of the two materials when exposed to elevated temperatures. Intumescent PVC tends to swell and plug the sleeve, thus creating its own barrier. Upon burning, a carboniferous char is left and remains throughout most of the test. Eventually, the char is totally consumed after prolonged exposure to elevated temperatures (1600 to 1800°F).

ABS is not intumescent and does not leave a residual char. The use of Fiberfrax insulation on the sleeve appears to have little effect on the performance of the assembly.

d) <u>Series No. 7</u>

The purpose of the single test in this series was to provide comparative data for copper plumbing systems. The test assembly consisted of 1½-in. copper lateral with P-trap entering a 1½-in. copper stack. The P-trap was filled with water. The temperatures recorded are shown in Figure 8. Paper placed against the vertical pipe above the tee burned without flame. Paper placed against the lateral ignited immediately. Thermocouple data indicated that the water in the P-trap had evaporated within 10 minutes.

VERTICAL TESTS

Table 4 presents a tabular summary of all test assemblies and test results. Throughout this series of tests, the floor structure consisted of a 4-in. thick reinforced concrete slab mounted on top of a small-scale furnace. The underside of the slab was protected with a 1-in. layer of Fiberfrax.

a) <u>Series B - Vented Assemblies</u>

The first three tests of this series were designed to indicate how essentially unprotected 4-in. ABS and PVC pipe would behave in the vertical mode when exposed to fire, and also, to serve as a checkout for the vertical furnace.

It was anticipated that vertical plastic pipe would burn more dramatically than horizontal pipe, and the first three tests confirmed that this was the case. It seemed inevitable that the flow of hot gases through vertical pipe would eventually cause the pipe to soften and tear, probably just below the first pipe support above the fire separation. The softened, separated section would collapse around the separation and possibly form a temporary seal if the pipe did not tear when it collapsed. The temporary seal, however, would shortly burn through, allowing furnace gases to escape and thus ignite the collapsed pipe.

Some specific differences were noted between ABS and PVC assemblies. In test No. 2 with PVC, flame was evident at the top of the stack after 20 minutes. At 22 minutes, the pipe had softened and tore away from the clamp, collapsing in a mass around the top of the sleeve thus creating a seal. At 35 minutes, the pipe seal was perforated and finally ignition of the PVC took place at 37 minutes. The "self-extinguishing" characteristic of PVC was only evident when the penetration to the furnace was covered. Removal of the cover caused reignition of the PVC.

In test No. 3, using ABS pipe, flames started to shoot out of the top of the pipe within 7 minutes, and reached 8 feet above the pipe after 14 minutes. The pipe became so soft that it collapsed along its longitudinal axis. The collapsed pipe created a seal to the furnace, but the ABS had ignited above the seal and continued to burn. The fire was extinguished with water at 15 minutes.

It was obvious, therefore, that preventing exposure to an open penetration required either a device to form a seal when the pipe softened, or a construction technique that would allow the plumbing to form an effective and reliable seal. Such a device is shown in Figure 9 and is based on a design patented by J.J. Blumenkranz[4].

In tests Nos. 4 and 5, a flapper valve assembly showed that, while the assembly was awkward to work with, a mechanical device could provide an effective seal when used with PVC and if a problem had not occurred in the support of the device, it is probable that the device would have worked with ABS as well. The tests did reveal that assemblies under load suffer severe stressing at elevated temperatures, and in comparison with horizontal assemblies, warpage is a more severe problem in vertical structures. For testing purposes it was necessary to construct parts from inconel to get an assembly that would last 2 hours in order to assess the principle.

In test No. 4, using 4-in. ABS pipe it appeared that the bottom flapper closed within 8 minutes. The pipe above the sleeve softened sufficiently that the top flapper was about 90 per cent closed after

30 minutes. The assembly was not properly anchored, however, and the concrete slab prevented the top flapper from closing completely. At 37 minutes, when the test was terminated, the pipe ignited at the top of the sleeve. Inspection of the apparatus after the test showed that the bottom flapper had warped under the weight and thus the seal effect had been lost, allowing hot furnace gases to travel up through the device.

This test was repeated in test No. 5 using 4-in. PVC pipe but with two modifications: 1) the assembly was properly anchored to the concrete slab, and 2) the 1/8-in. carbon steel flapper on the exposed side was replaced with 1/8-in. inconel plate. In this test, the bottom flapper completely closed within approximately 21 minutes. Heat transfer caused the pipe in the sleeve and just above to disintegrate first to the typical carboniferous ash, and finally to disappear completely. This took approximately 62 minutes, at which time the top flapper closed completely. The test was terminated after 2 hours. Post test inspection showed that again warpage had occurred in the exposed flapper - this time in the hinge - causing a slight opening to form in the seal. The photographs in Figure 10 show the apparatus and pipe after the test.

Previous tests provided the principles upon which the vertical compartment concept of tests Nos. 6 through 8 was based. It was reported in the first progress report that a sleeve placed at 45° would allow a vertical separation to maintain its integrity for at least one hour, depending on the length of the sleeve. In all tests involving sleeves, the sleeve was substantially cooler on the unexposed side of a wall due to convective heat loss to the ambient environment. The insulated compartment design shown in Figure 11 represented an attempt to duplicate these conditions. Ideally, a much larger compartment would more closely represent the infinite condition of an open ambience. In construction practice, this assembly could be represented by installing a protective false ceiling below the structural floor and running a 45° sleeve through the false ceiling. A 45° angle is the largest permissible angle in an offset without introducing hydraulic jump problems(5).

Tests Nos. 6 through 8 utilized the same structure, the only modification for test No. 8 being that the 45° sleeve was insulated with ½-in. Fiberfrax. Figure 12 (photograph (a)), illustrates the compartment and pipe arrangement.

Test No. 6, using 3-in. PVC pipe, indicated that this structure did indeed delay the propagation of fire through the horizontal fire separation. In this test, hot gases began to escape the system after 69 minutes, with total collapse and fire propagation occurring at 76 minutes.

In this test, it was not possible to view the assembly below the concrete slab, however, observations of the assembly above the slab and thermocouple data clearly indicated events not readily visible. Figures 13(a) and (b) represent the thermocouple data. Within 7 minutes the exposed end of the pipe was consumed, allowing hot gases to escape through the system. These hot gases caused the pipe above the concrete to ripple and deform slightly, but the integrity of the system was not damaged. Between 20 and 25 minutes into the test it was apparent that the flow of gases was slowing down and finally stopped, suggesting that a seal had formed in the 45° sleeve. From then until about the 65 minute mark there was little change. There was a continuous flow of light smoke from the stack during this period suggesting that some PVC was slowly degrading, possibly the collapsed elbow within the compartment. Thermocouples within the compartment indicated that the temperature was rising within the compartment continually until at 65 minutes smoke and pressure-driven gases started to flow from the stack indicating that the seal was broken. At 69 minutes a hole formed in the pipe and at 76 minutes the pipe collapsed and ignited. It was apparent that the whole pipe was charred inside at this time.

Figure 12, photographs (b) through (d) show the condition of the sleeves, the compartment, and the collapsed pipe after the test. It is noted that only a small amount of ash remained in the compartment.

Test No. 7 utilized the same assembly with 3-in. ABS pipe. However, in the test assembly, the stack extended approximately 18-in. above the uppermost clamp. When the exposed end of the pipe burned and hot gases started to flow through the stack, the ABS softened. The pipe started to sag around the top of the sleeve, but the 18-in. section above the clamp folded over, creating a seal and shutting off the flow of gases. This is unrealistic, as one would not expect this to happen in a proper installation. With this seal formed, however, a hole did not appear in the pipe at the edge of the sleeve until approximately 55 to 60 minutes. Photographs in Figure 14 illustrate this test.

Test No. 8 repeated this test, correcting for the extended pipe, and insulating the 45° sleeve with ½-in. Fiberfrax. In this test, the flow of hot gas through the stack caused the pipe to soften to such an extent that the pipe tore at the clamp and collapsed around the penetration creating a seal at approximately 10 minutes. By 21 minutes, there was fuming around the pipe in the sleeve, and by 34 minutes no material was left in the sleeve. At 40 minutes, the pipe that had collapsed around the sleeve ignited.

b) <u>Series C - Non-Vented Pipe</u>

Two tests were run to determine the behaviour of plastic pipe in non-vented applications. In each test, two lengths of 2-in. DWV pipe were situated so that they penetrated the concrete floor and were secured about 5 ft above the concrete. The pipes were capped and sealed at both ends to represent a non-vented situation. Different sleeve lengths were used to determine the effect of various lengths on the duration of the system integrity. The arrangement is shown in Figure 15.

In test No. 1, using PVC, thermocouples were placed at the top of the sleeves and on each pipe 12 in. above the sleeve. Plots of the temperature recordings are shown in Figure 16. In test No. 2 using ABS, thermocouple locations were altered so that on each sample thermocouples were located on the sleeve 1 in. above the concrete, 1 in. below the top of each sleeve, and 1 in. above the sleeve on the pipe itself. The plots of these data are shown in Figures 17 and 17(a).

Both tests ran the full 2-hour period with no indication that failure was near. In fact, the graphs in Figures 16, and 17 and 17(a) show that the temperature at the top of the sleeves was quite cool.

Examination of the samples after the test revealed that in test No. 1 a carboniferous ash had formed a seal across the diameter of the pipe approximately 1 in. above the concrete. The ash was quite brittle and very thin in the middle. No signs of degradation were evident more than 3 in. above the concrete. Figure 18 shows the ash after the sleeve had been removed.

The ABS pipe in test No. 2 did not form the same type of ash because ABS is not an intumescent material, as is PVC. Examination of the samples after the test showed that the ABS had disintegrated with no residual ash to a point approximately 1 to 2 in. above the concrete. The next 2 inches of pipe revealed degradation in the form of char formation, brittleness, and some thinning in wall thickness. Above that level, the pipe was essentially untouched.

The results of the two tests of series C raises some interesting speculation. In both tests, the pipes remained intact and were virtually unblemished above the sleeves after a 2-hour test. In fact, pipe destruction ended only a couple of inches above the top of the concrete slab. This situation would approach the optimum when a sleeve as thin as possible is used.

The same situation does not occur, however, when a section of pipe collapses over the top of the sleeve creating a seal. This creates a non-vented condition. Eventually the pipe becomes perforated creating a vented situation with ignition following shortly thereafter. This has been the case throughout the vertical test program. The difference in performance is probably attributable to a combination of two factors. Firstly, the sleeve wall thickness is greater and thus more heat is conducted to the pipe, and secondly, there is no insulating cushion of stagnant air.

The question of pipe wall thickness still remains for non-vented applications. Many non-vented applications would use thin-wall pipe, probably with wall thickness of approximately 0.06 in. The pipe used in these tests had wall thicknesses of 0.17 and 0.15 in. for PVC and ABS respectively. Inspection of the pipe after the tests, however, showed that there was no deterioration in the pipe more than a few inches above the concrete slab, so using a sleeve of sufficient length should provide adequate protection.

In all test assemblies in the vertical mode, the space between the form and the sleeve was carefully packed with Fiberfrax to ensure that no leaks occurred around the assembly. Also, every sleeve had been anchored in place with a simple brace so that it would remain in place after the pipe burned away. Failure to do this once in test No. 3 forced premature termination of the test.

Finally, when using sleeves, it is desirable to have as little of the sleeve as possible in the fire compartment. For example, in the non-vented tests, the bottom of the sleeve was flush with the bottom of the concrete.

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TABLE 1

HORIZONTAL TESTS

Test	Pipe Size and Material	Pipe Assembly Construction	Test Duration	Remarks
Series No. 4				
Test 4	ABS 2" × 2"	Steel Sleeve W/Weighted Flapper; ½" Insulation	30 min.	Flapper failed to make seal - see Figure 2
Test 5	PVC 1½"	4" Long Steel Sleeve W/Guillotine; ½" Insulation	115 min.	Partial seal caused by welding - see Figure 3
Series No. 5				
Test 1	PVC 1½"	5" × 10" × 8" Box Filled W/Sand; Guillotine; 3" Sleeve	120 min.	See Figure 4
Test 3	ABS 1½"	As in Test 1	120 min.	
Test 5	PVC 1½"	As in Test 1	120 min.	
Test 6	ABS 1½"	As in Test 1	120 min.	
Test 4	ABS 1½"	As in Test 1, Compartment Filled W/Gypsum	31 min.	Gypsum bridged allowing direct flow of furnace gases

Cont'd

TABLE 1 (Cont'd)

HORIZONTAL TESTS

Test	Pipe Size and Material	Pipe Assembly Construction	Test Duration	Remarks
Series No. 6				
Test 1	ABS 1½" × 1½"	Double Swivel Flapper Assembly, 4" Steel, ½" Insulation	120 min.	See Figure 5
Test 2	ABS 1½" × 2"	As in Test 1	120 min.	
Test 3	PVC 1½" × 1½"	As in Test 1	120 min.	
Test 4	ABS 3" × 3"	As in Test 1	120 min.	
Test 5	PVC 3" × 3"	As in Test 1	120 min.	
Test 6	PVC 3" × 3"	As in Test 1 Except no Insulation Used	120 min.	
Test 7	PVC 1½" × 2"	As in Test 6	120 min.	
Test 8	ABS 1½" × 2"	As in Test 6	120 min.	
Series No. 7				
Test 1	Copper 1½" x 1½"	P-Trapped Lateral Into Tee and Vertical Riser. P-Trap filled With Water	60 min.	

TABLE 2

VERTICAL TESTS

Test	Pipe Size and Material	Pipe Assembly Construction	Time Duration	Remarks
Series B				
2	PVC 4"	Vertical Pipe with 12" Steel Sleeve	53 min.	Failure @ 37 min.
3	ABS 4"	Identical to Test 1	15 min.	
4	ABS 4"	12" Sleeve W/Flapper on each end	37 min.	Improper mounting of sleeve caused premature failure
5	PVC 4"	Identical to Test 4	120 min.	See Figure 9
6	PVC 3"	Sleeved Pipe Penetrating Small Compartment @ 45° Prior to Penetration of Concrete Floor	76 min.	See Figure 11
7	ABS 3"	Identical to Test 6	87 min.	Longer run
8	ABS 3"	Identical to Test 7, 45° Sleeve Insulated	40 min.	Artificial seal prevented
Series C				
1	PVC 2"	2 Non-Vented Pipes Sleeved 12" and 16"	120 min	See Figure 15
2	ABS 2"	Identical to Test 1	120 min.	

TABLE 3

HORIZONTAL TEST ASSEMBLIES

Test Number	Material	Assembly Description	Test Duration
Series No. 4			
Test 4	ABS	2-in. horizontal pipe into 2-in. vertical pipe; sleeved; and insulated with ½-in. Fiberfrax at wall penetration. Simple flapper.	30 min.
Test 5	PVC	1½-in. PVC, ½-in. thick Fiberfrax insulation and 4-in. sleeve at wall penetration. Exposed end of sleeve equipped with 1190 gm. guillotine.	1 hr. 55 min.
Series No. 5			
Test 1	PVC	1½-in. PVC with 3-in. sleeve at wall penetration. Exposed side consisted of 5 × 10 × 8-in. compartment with 1030 gm. guillotine on front side. Compartment filled with sand.	2 hr.
Test 2	ABS	As in Test 1.	Test cancelled @ 10 min. furnace malfunction
Test 3	ABS	As in Test 1. Guillotine wt. 1115 gm.	2 hr.
Test 4	ABS	As in Test 1. Compartment filled with gypsum. (USG #1, Terra Alba, Hydrous Calcium Sulphate)	31 min.
Test 5	PVC	As in Test 1	2 hr.
Test 6	ABS	As in Test 1, larger particle size sand.	2 hr.
Series No. 6			
Test 1	ABS	Double flapper assembly. Pipe wrapped in ½-in. Fiberfrax insulation inside sleeve. 4-in. long sleeve equipped with swivel flapper on each end. Flapper weights approx. 530 gm. each. Vertical riser 1½-in. with single sanitary tee.	2 hr.

Cont'd

TABLE 3 (Cont'd)

HORIZONTAL TEST ASSEMBLIES

Test Number	Material	Assembly Description	Test Duration
Series No. 6 (Cont'd)			
Test 2	ABS	As in Test 1; weights approx. 700 gm. each; 1½-in. horizontal; 2-in. vertical pipe; riser anchored.	2 hr.
Test 3	PVC	As in Test 1; 1½-in. horizontal and vertical pipe; weights approx. 700 gm; riser anchored.	2 hr.
Test 4	ABS	As in Test 1; 3-in. horizontal and vertical pipe; weights approx. 1675 gm; riser anchored.	2 hr.
Test 5	PVC	As in Test 1; 3-in. horizontal and vertical pipe; weights approx. 1650-1675 gm; riser anchored.	2 hr.
Test 6	PVC	As in Test 1 except no Fiberfrax insulation used; 3-in. pipe; weights 1550-1670 gm; riser anchored.	2 hr.
Test 7	PVC	As in Test 1; no Fiberfrax insulation; 1½-in. horizontal into 2-in. vertical riser (anchored); weights 650 gm.	2 hr.
Test 8	ABS	Same as Test 7	2 hr.
Series No. 7			
Test 1	Copper	1½-in. Copper piping. P-trapped lateral into sanitary tee and riser. P-trap filled with water.	

TABLE 4

VERTICAL TEST ASSEMBLIES

Test Number	Material	Assembly Description	Test Duration
Series B			
Test 1	ABS	4-in. pipe vertically mounted; 12-in. long sleeve at floor penetration.	8 min.
Test 2	PVC	Identical to Test 1	53 min. Failure at 37 min.
Test 3	ABS	Identical to Test 1	15 min.
Test 4	ABS	Vertical flapper assembly; 12-in. sleeve with flapper on each end.	37 min.
Test 5	PVC	Identical to Test 4	2 hr.
Test 6	PVC	9- × 17- × 20-in. compartment suspended from floor; insulated; sleeved 3-in. pipe penetrated vertical side @ 45° and floor @ 90°.	1 hr.
Test 7	ABS	Identical to Test 6	1 hr. 27 min.
Test 8	ABS	Identical to Test 7 except 45° sleeve insulated with ½-in. Fiberfrax.	40 min.
Series C			
Test 1	PVC	2 non-vented 2-in. pipe penetrate floor; pipes sleeved 12 and 16 in. respectively.	2 hr.
Test 2	ABS	Identical to Test 1	2 hr.

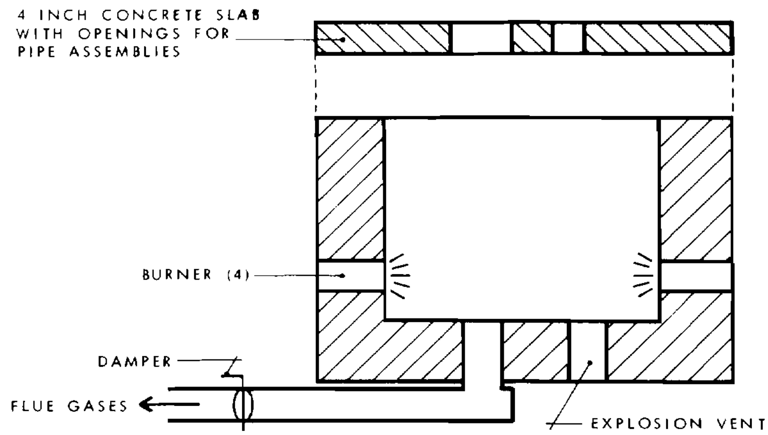


Figure 1

Vertical Plumbing Assemblies Test Furnace

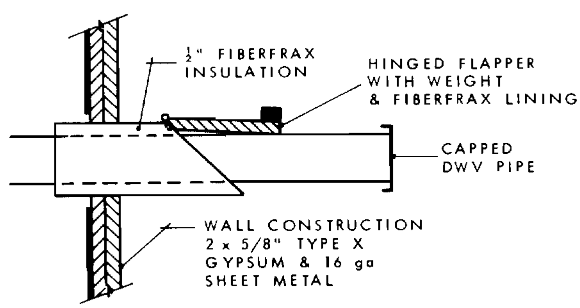


Figure 2

Hinged Flapper Assembly

Series No. 4, Test No. 4

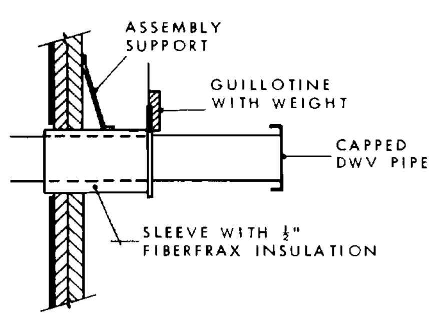


Figure 3

Simple Guillotine Assembly

Series No. 4, Test No. 5

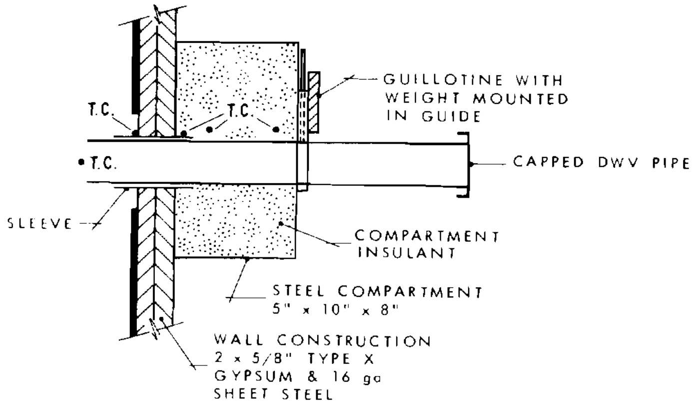
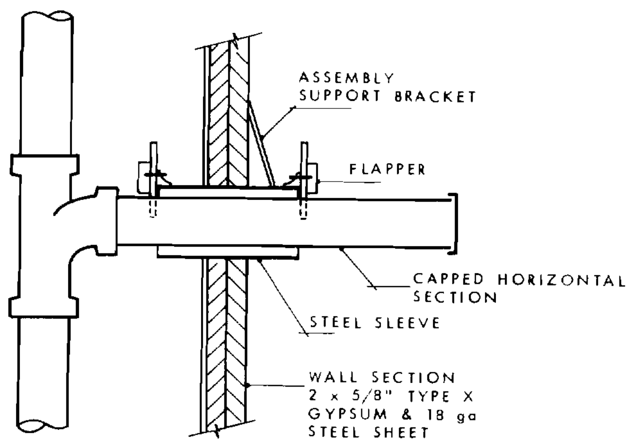
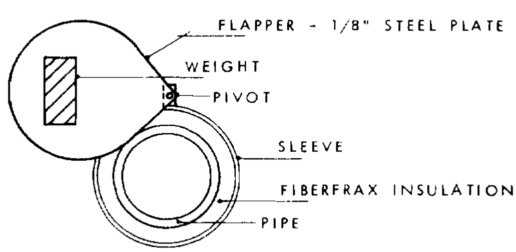


Figure 4

Guillotine and Insulated Compartment Assembly



a) Side View

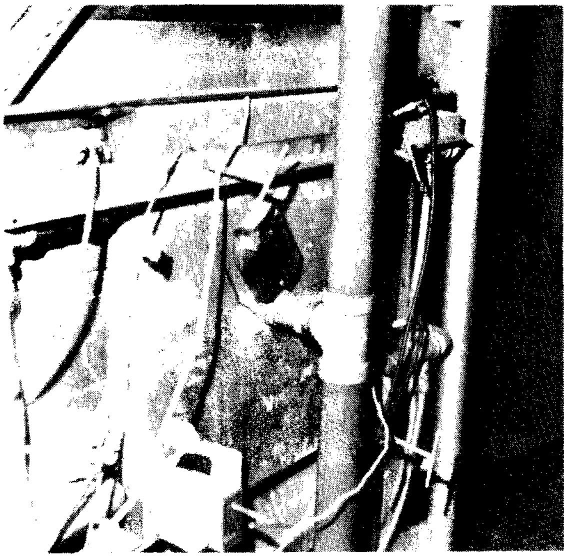


b) End View

Figure 5

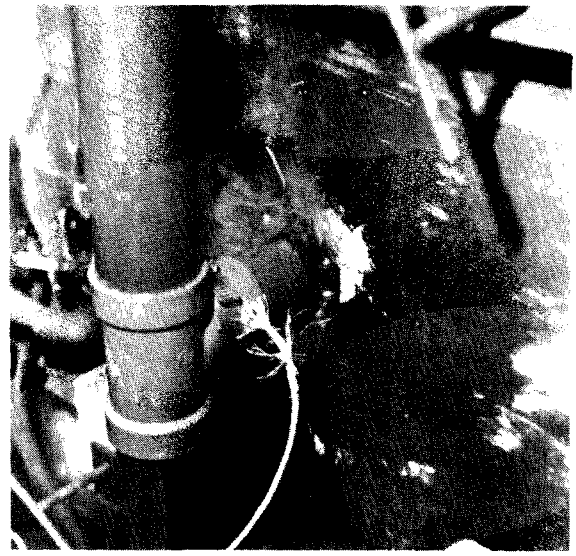
Double Flapper Mechanism

a) Side View b) End View



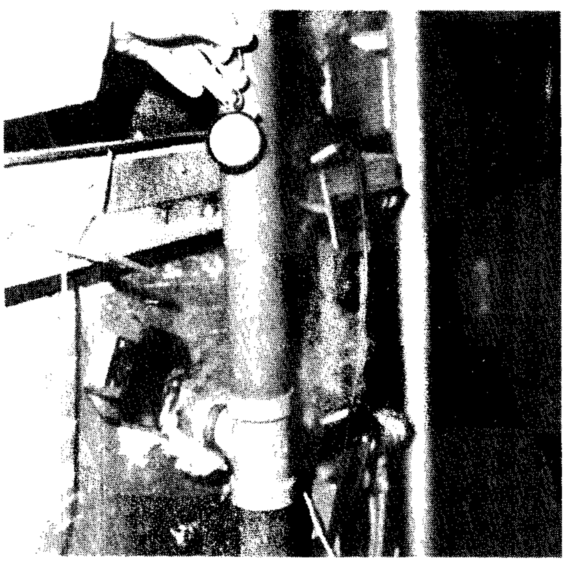
(a)

Prior to Test



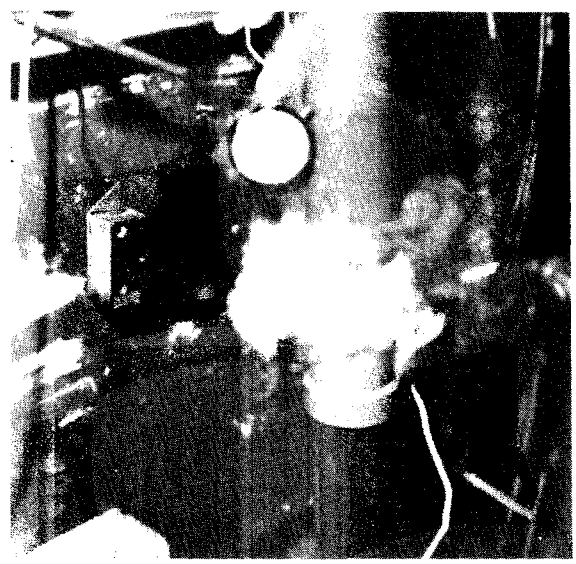
(b)

Approximate Time - 20 min.



(c)

t = 28 min.



(d)

t = 35 min.

Figure 6

Time Progression of Swivel Flapper. Unexposed Side.

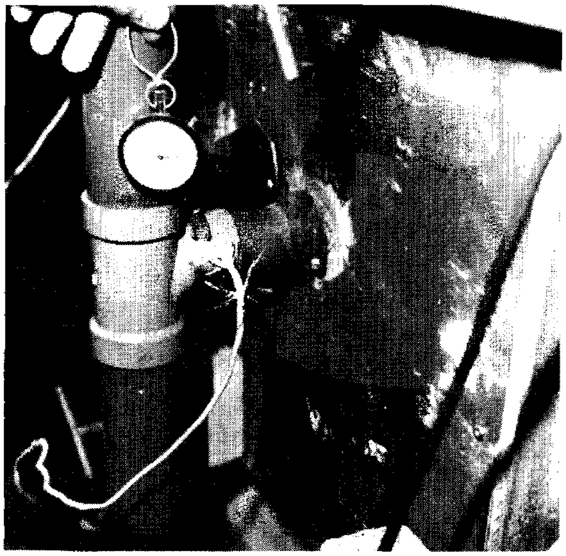
a) Prior to Test

b) Approximate Time - 20 min.

c) t = 28 min.

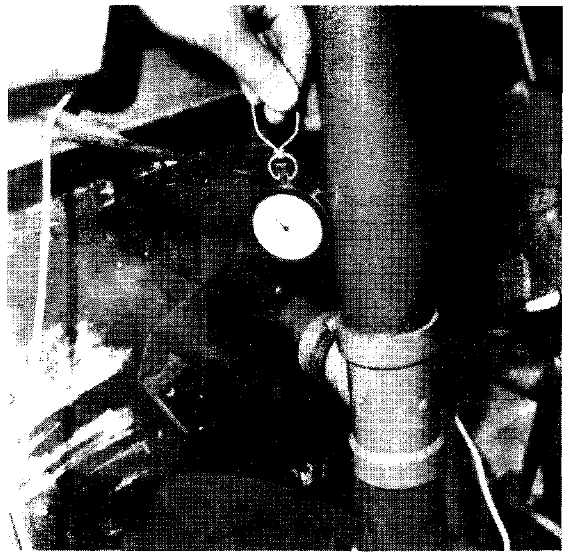
d) t = 35 min.

(Cont'd)



(e)

t = 45 min.

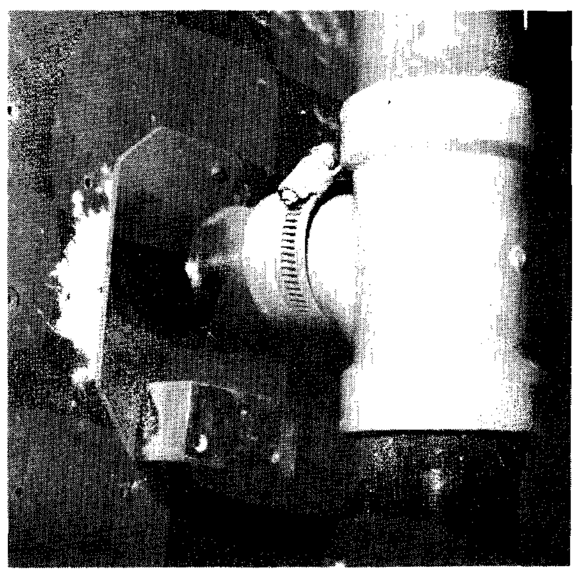


(f)

t = 45 min.

(g)

After Test is Over



(h)

After Test is Over

Figure 6 (Cont'd)

Time Progression of Swivel Flapper. Unexposed Side (Cont'd)

e) t = 45 min.

f) t = 45 min.

g) After Test is Over

h) After Test is Over

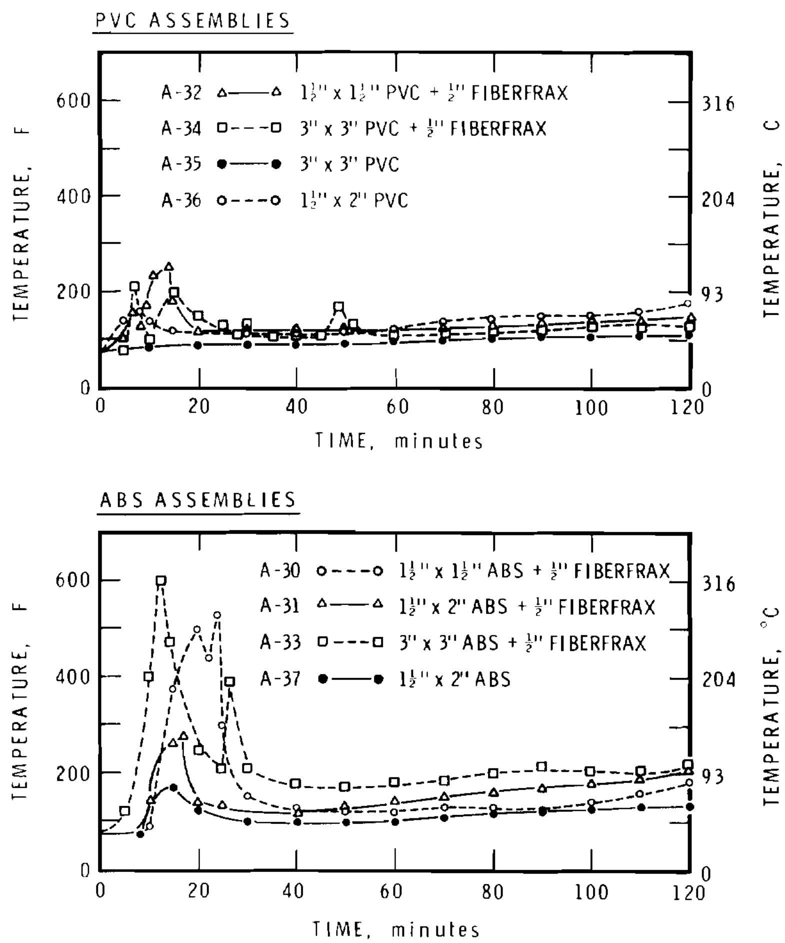
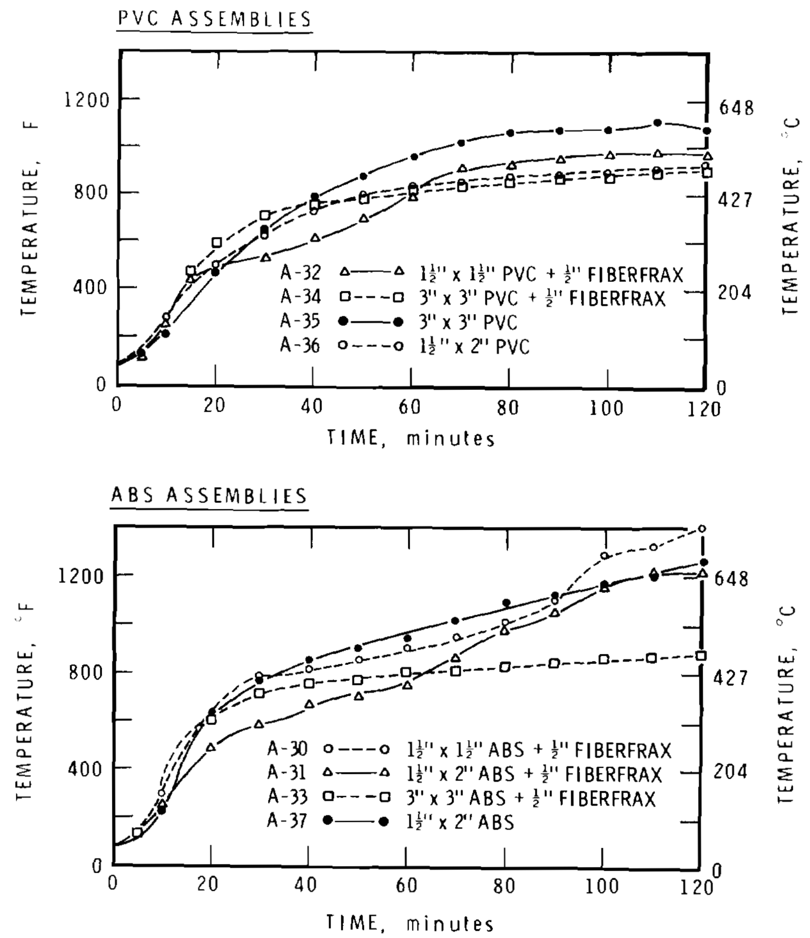


Figure 7(a)

Air Temperature Inside Tee



(T.C. 7)

Figure 7(b)

Sleeve Temperature - Unexposed Side

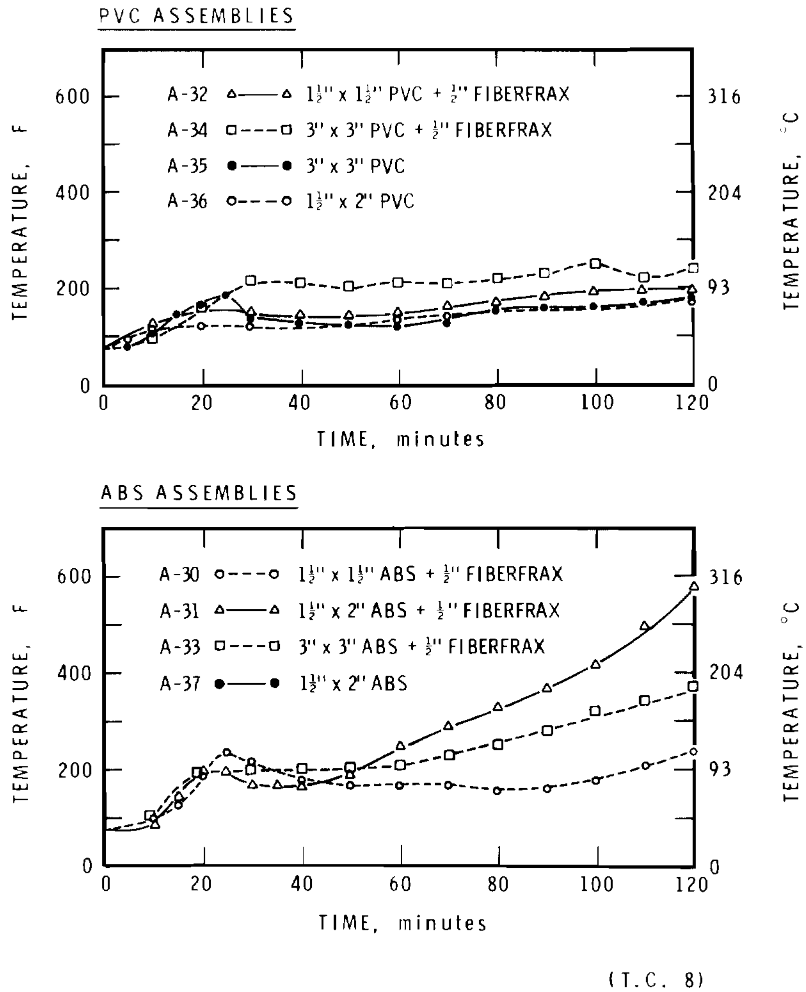


Figure 7(c)

Temperature - Exterior of Tee

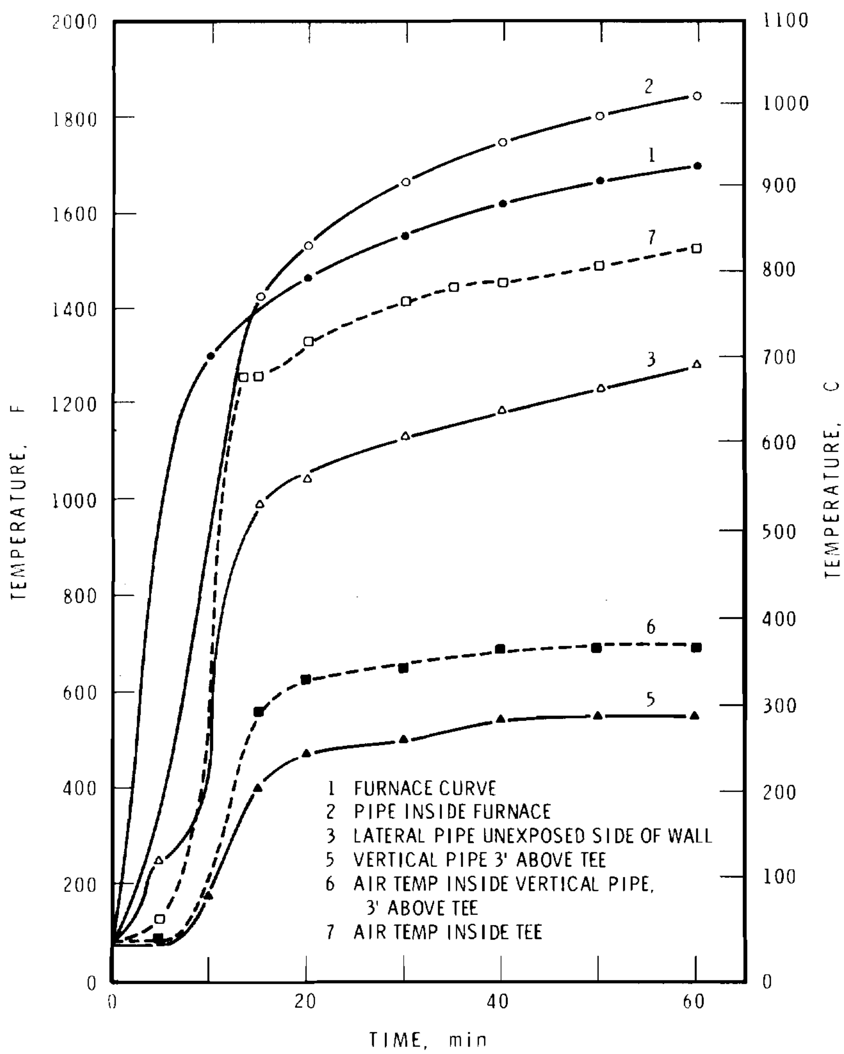


Figure 8

Temperature Record for 1½" Copper Pipe.

Test A-38

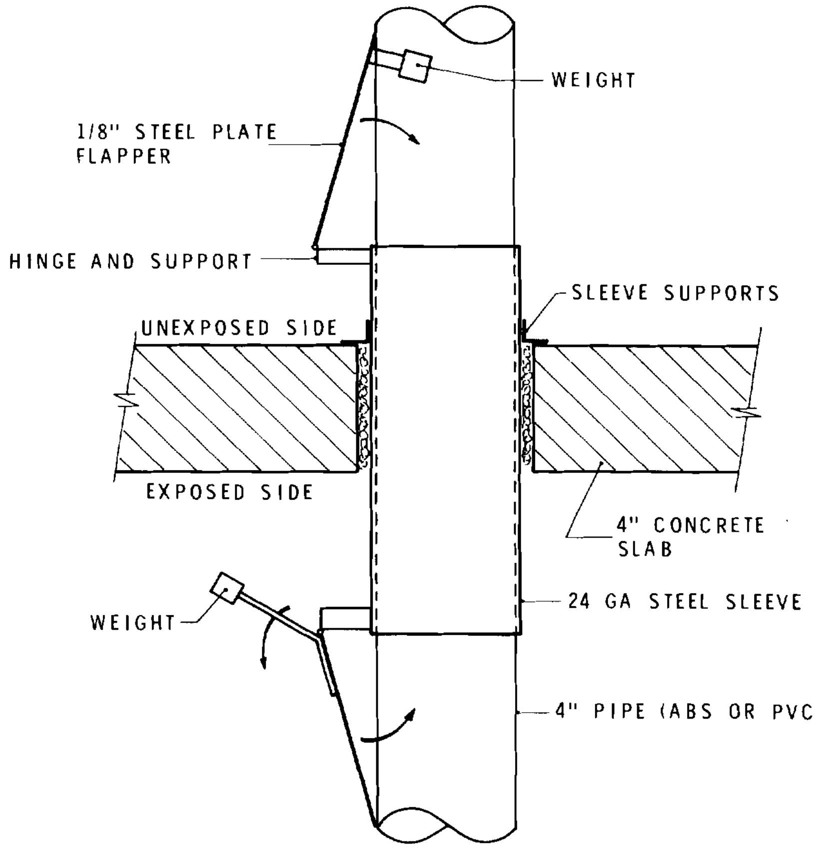
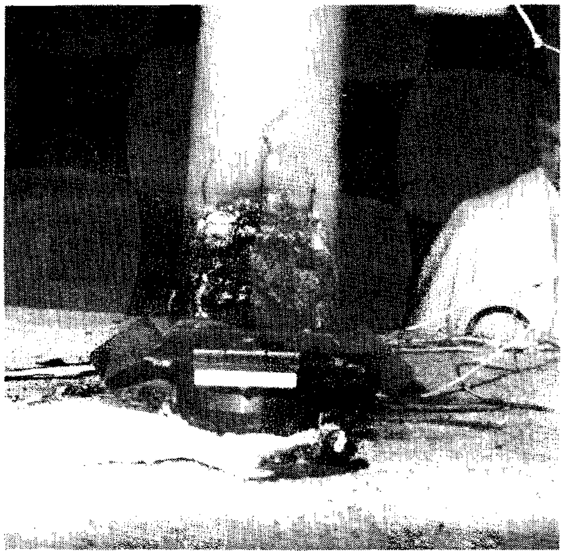
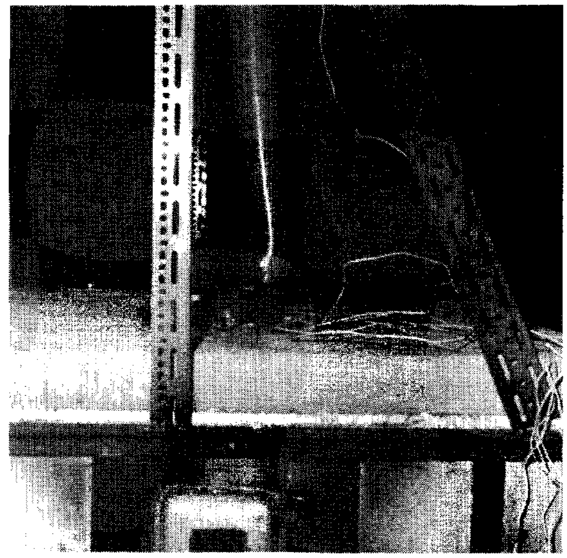


Figure 9
Double Flapper Device For Vertical Pipe



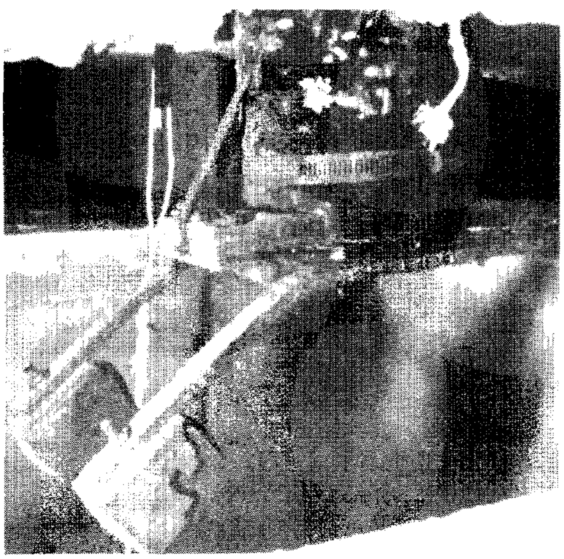
(a)

Back View - Top of Flapper Assembly After Test B-5



(b)

Side View - Test B-5



(c)

View of Exposed Portion - After Test B-5

(d)

Carboniferous PVC Ash Formed Above Top Flapper

Figure 10

Apparatus and Pipe After Test

(a) Back View - Top of Flapper Assembly After Test B-5

(b) Side View - Test B-5

(c) View of Exposed Portion - After Test B-5

(d) Carboniferous PVC Ash Formed Above Top Flapper

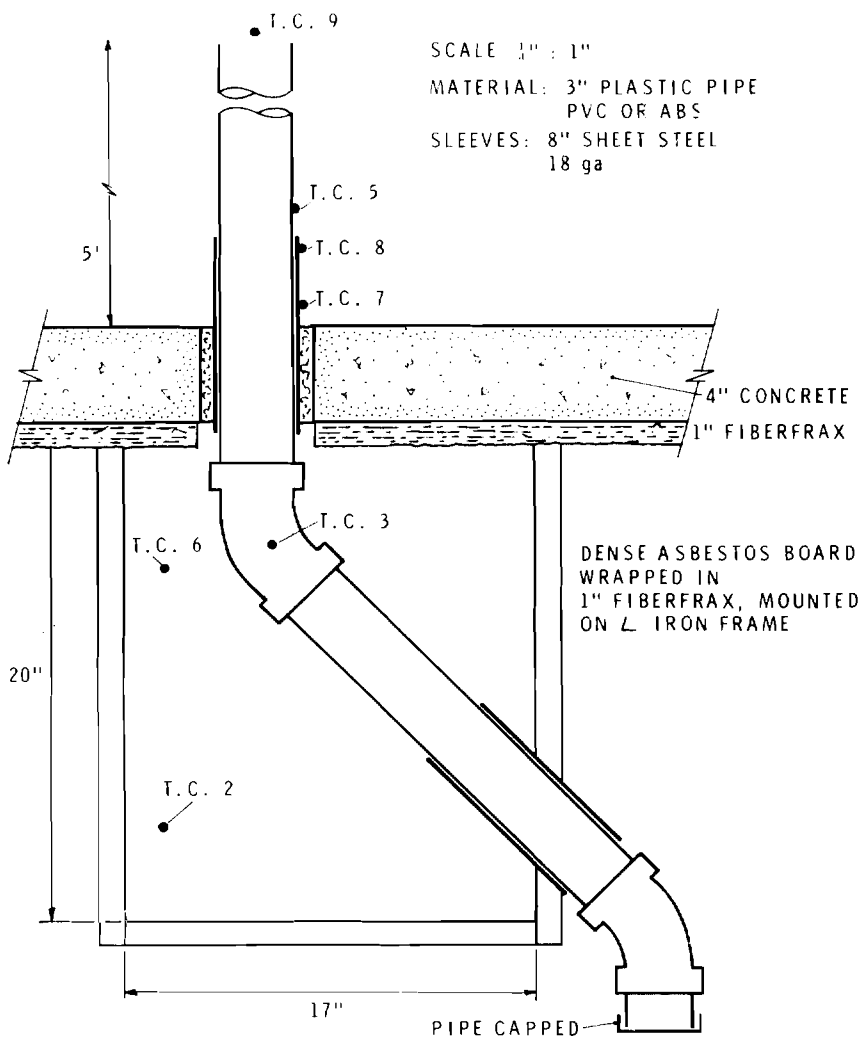
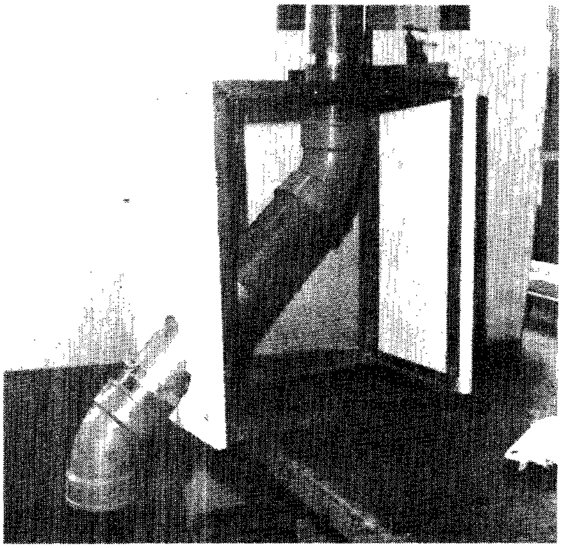


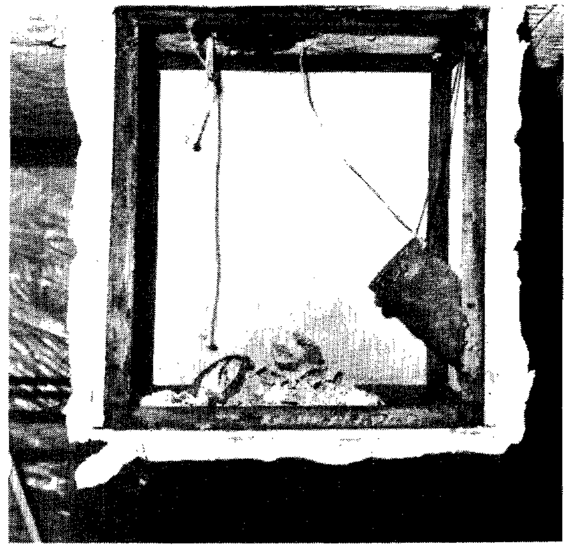
Figure 11

Insulated Compartment Design



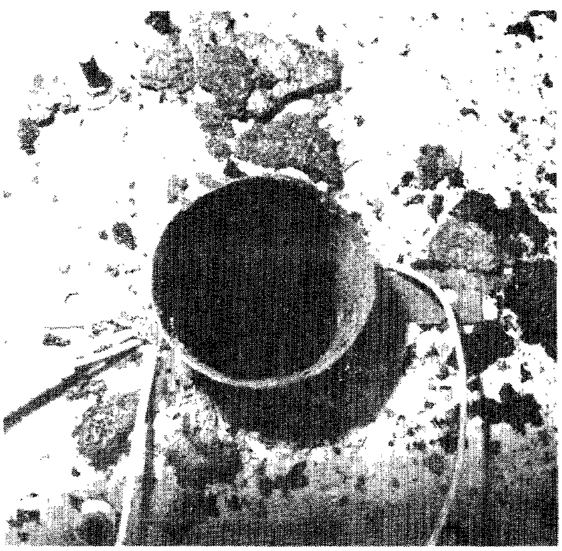
(a)

Assembly Before Exposure



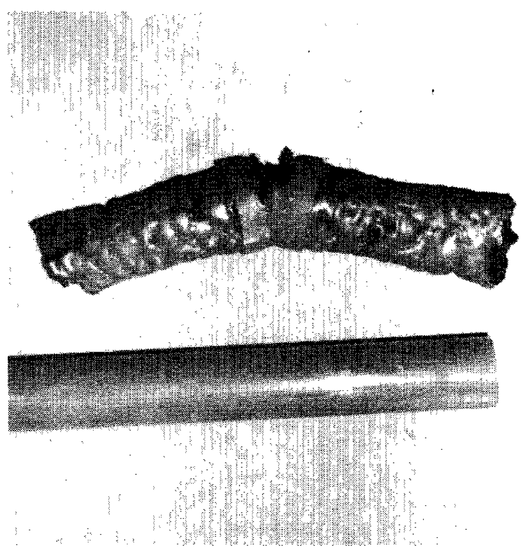
(b)

Compartment After Test -
Front Panel Removed



(c)

Sleeve Through Concrete Floor
Viewed From Above After Test



(d)

Section of Collapsed Pipe After Test
Compared to Original Pipe (3" PVC)

Figure 12

Vertical Test B-6

(a) Assembly Before Exposure

(b) Compartment After Test - Front Panel Removed

(c) Sleeve Through Concrete Floor Viewed From Above After Test

(d) Section of Collapsed Pipe After Test Compared to Original Pipe (3" PVC)

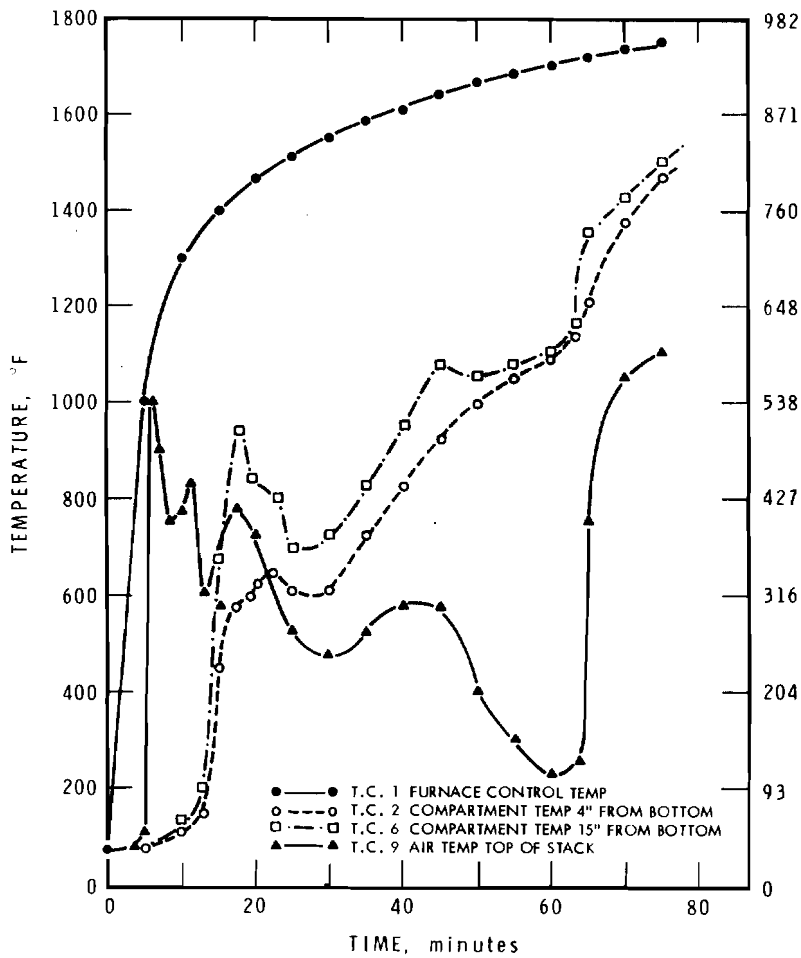


Figure 13(a)

Thermocouple Data for PVC Assembly Test B-6

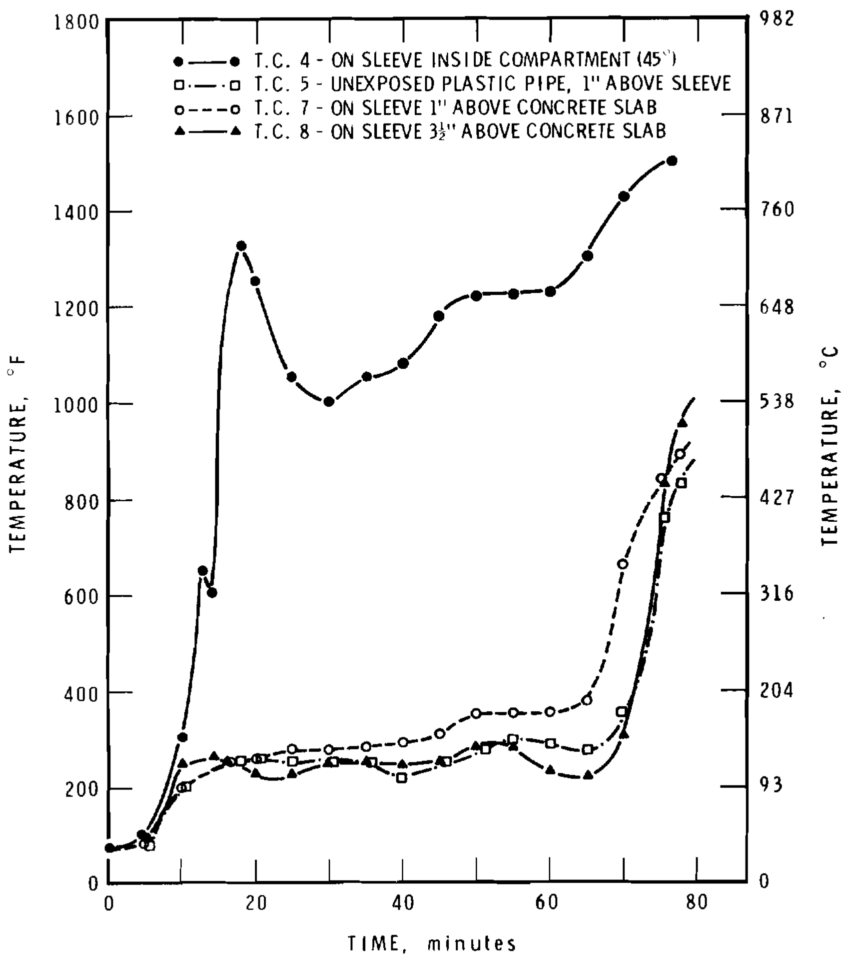


Figure 13(b)

Thermocouple Data for PVC Assembly Test B-6

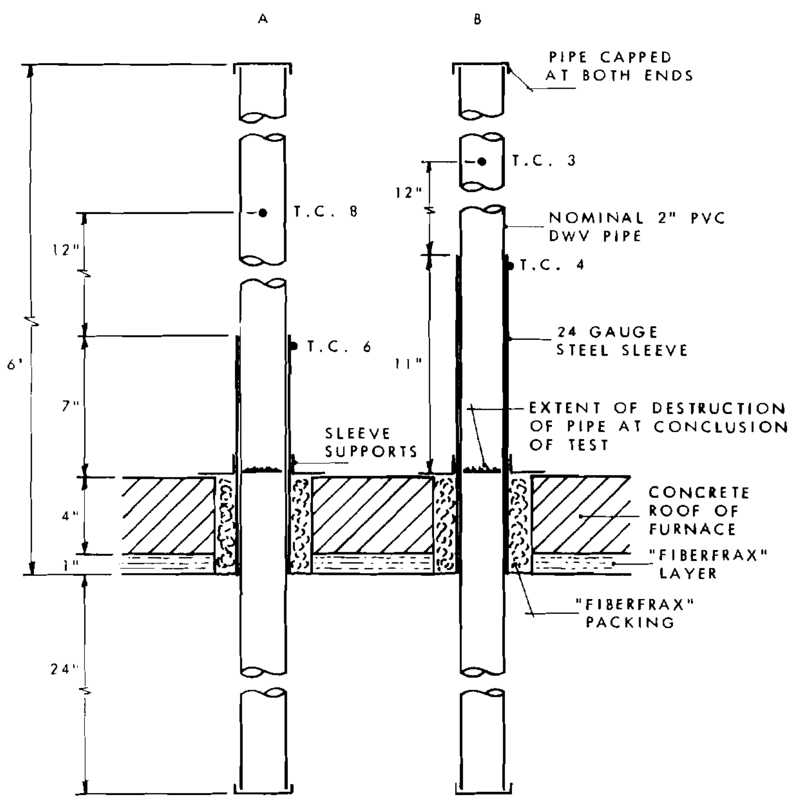
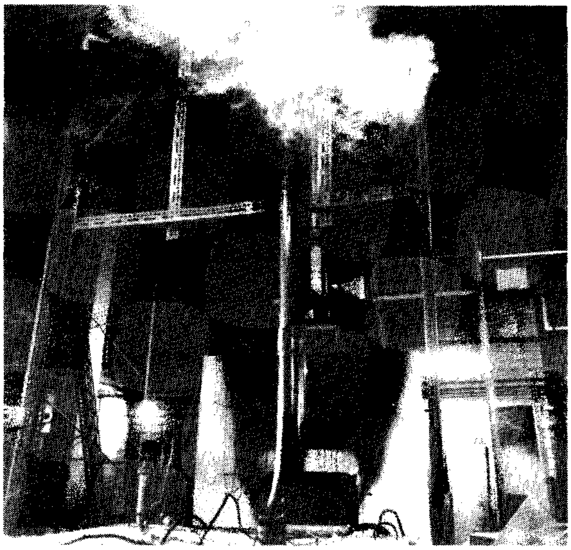


Figure 15

Test Arrangement for Non-Vented PVC Assembly



(a)

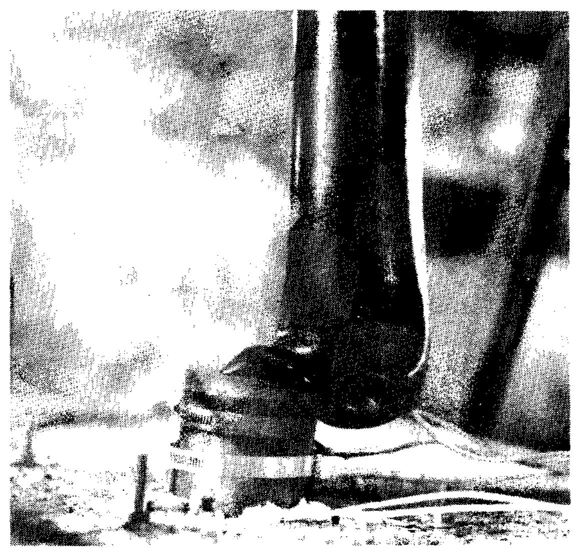
Smoke From Stack Early in Test
Pipe is Starting to Sag

(b)

Pipe Folding Over Creating a Seal

(c)

Hole Forming at Top of Sleeve
After Approximately 1 hr



(d)

Same as (C) Viewed From Other Side

Figure 14

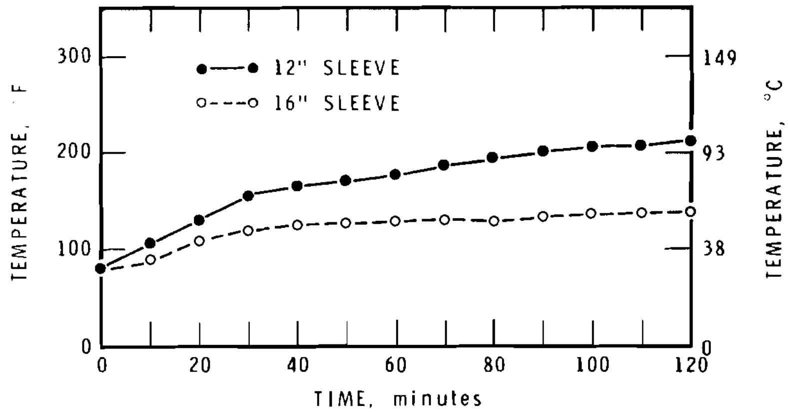
Vertical Test B-7

(a) Smoke From Stack Early in Test Pipe is Starting to Sag

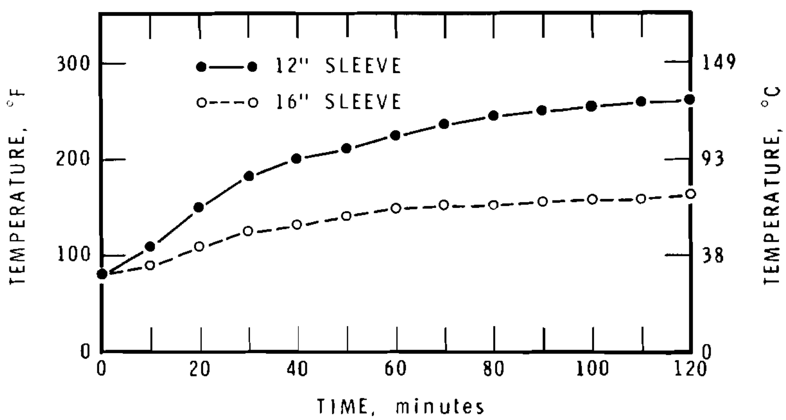
(b) Pipe Folding Over Creating a Seal

(c) Hole Forming at Top of Sleeve After Approximately 1 hr

(d) Same as (c) Viewed From Other Side



a) Temperature of ABS Pipe 1" Above Sleeves



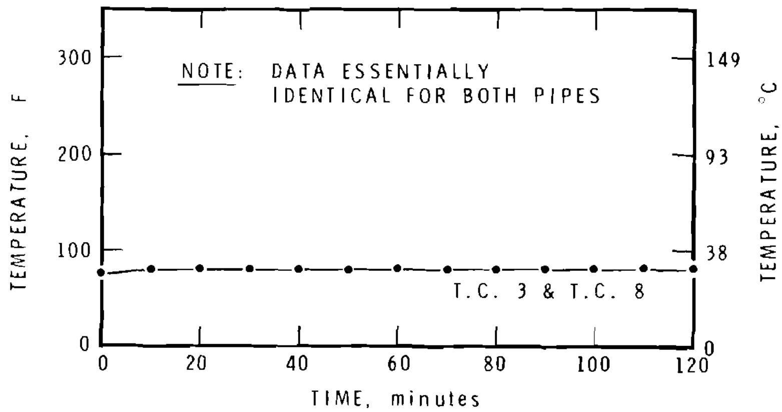
b) Temperature at Top of Sleeves vs Time

Figure 17

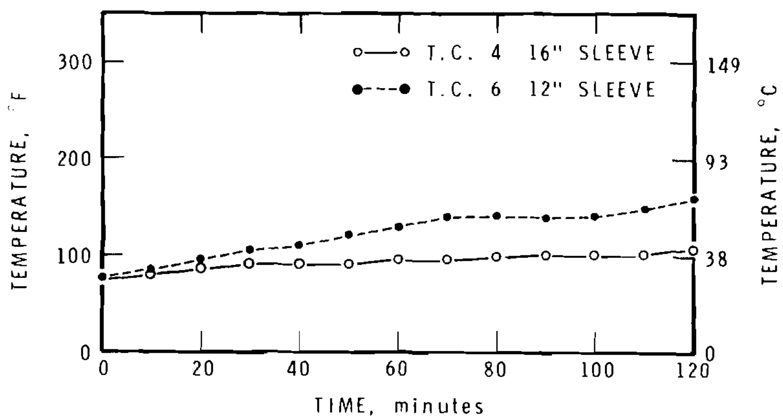
Vertical Test C-2

a) Temperature of ABS Pipe 1" Above Sleeves

b) Temperature at Top of Sleeves vs Time



a) Temperature of PVC Pipe 12" Above Sleeves



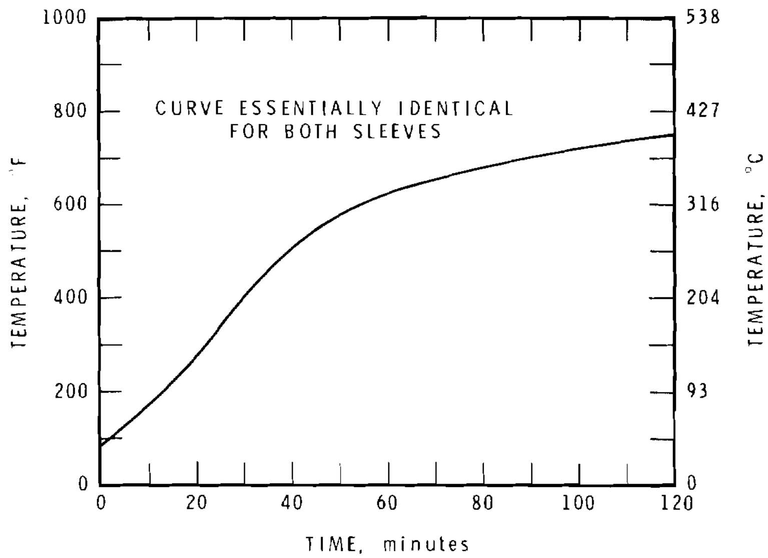
b) Temperature at Top of Sleeves vs Time

Figure 16

Vertical Test C-1

a) Temperature of PVC Pipe 12" Above Sleeves

b) Temperature at Top of Sleeves vs Time



Temperature of Sleeve 1" Above Concrete

Figure 17(a)

Vertical Test C-2

Figure 18

Residual Ash - 2" PVC

Non-Vented