

BURIED facts

Fires in Sewers and Culverts

Akron, Ohio, June, 1977

Three thousand gallons of petroleum naphtha and isopropyl alcohol dumped into the city's sewer system by vandals earlier in the evening suddenly explodes, rocking the city and causing \$10 million in damage.

Nashville, Tennessee, March, 1978

A gasoline tanker attempting to avoid a collision swerves, jackknifes, and overturns, pouring more than 8,000 gallons of flaming gasoline into a major storm sewer, blowing manhole covers in the air, and sending 10-foot flames and columns of smoke billowing from the manholes.

**Louisville, Kentucky,
February, 1981**

\$21 million in property damage, \$350 million in lawsuits, and a \$6 million repair bill that is still rising are the results of explosions in more than two miles of sewer lines, after hexane, a volatile and toxic chemical, is accidentally leaked into the sewer systems from a nearby grain processing plant.

The explosions that rocked Louisville, Nashville and Akron underscore the increasing vulnerability of the nation's utilities to damage from fires and explosions. What can be done to protect the billions of dollars worth of pipe presently in use? At best, procedures can be developed which enable the proper authorities to react quickly and effectively when notified of a pipeline fire or fuel spill. For projects in the planning stages, however, noncombustible pipe materials can be used to mitigate the consequences of fuel spills, gas leaks and fires of incendiary nature.



FLAMMABLE MATERIALS

The National Fire Protection Association, which is dedicated to promoting the science and improving the methods of fire prevention and protection, published Bulletin NFPA No. 328 which deals specifically with the consequences of combustible liquids and gases entering underground structures. The Bulletin states:

"Manholes, sewers and similar underground conduits have long been recognized by fire protection engineers as constituting areas where fire and explosion hazards of some severity may exist. Modern civilization, accompanied by the increase in number of gasoline service stations, solvent disposal operations, dry cleaning establishments, fuel gas production and distribution facilities, refrigeration plants, and many other industrial activities with potentially dangerous gas vapor by-products make the safe operation of underground structures more difficult each year."

Fuel spills often result from accidents involving tanker trucks. The fuel pouring from these trucks frequently flows into storm sewers through curb inlets and manholes, and, unless consumed by fire, eventually pollute the receiving waterway. Similarly, fuel enters sanitary sewers through manhole covers, interconnections prevalent between older storm and sanitary sewerage systems, illegal connections and dumping. Fuel spills on, or near, overpasses can result in the flammable liquid flowing through culverts. Leaks from pipelines and storage tanks of natural gas and liquified petroleum gas, LPG, have contributed to numerous fires and explosions, particularly while construction or maintenance was proceeding in the immediate area. The vast extent of the network of natural gas pipelines and storage facilities directly accounts for the high frequency of leaks from damage caused both by corrosion and nearby excavation.

Petroleum base linings and coatings applied to sewer and culvert pipe during manufacture provide another source of flammable materials. Metal pipe is most often lined and coated with such common substances as asphalts, bitumens, plastics and coal tars, because of its susceptibility to electrolytic and galvanic corrosion. Plastic pipe contains copious quantities of compounds which, depending on specific formulation, can contribute fuel to the fire.

SOURCE OF IGNITION

Fuel originating from overturned tanker trucks frequently ignites during the collision, or shortly thereafter, from sparks or contact with hot metal. Fuels or gases which enter a pipeline mix with air to form an explosive mixture which can be ignited by static electricity, construction or maintenance personnel lighting matches, or electrical equipment at pump stations and treatment plants. An often overlooked source of culvert fires is children building fires in the pipe during low water periods. Once started, the fire will propagate the

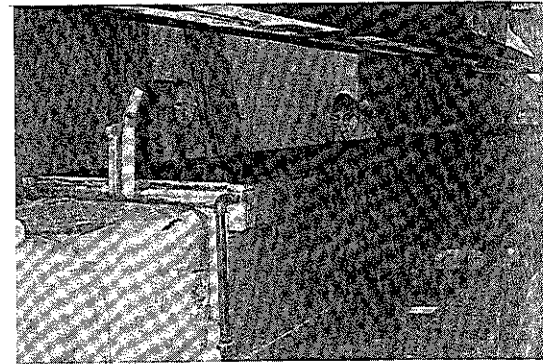
entire length of the culvert provided there is a flow of air through the line and a continuous fuel source such as a flammable lining. The lining will liquify under the intense heat and flow down the sides of the pipe to the invert, where it burns as it flows toward the culvert outlet. Lined storm and sanitary sewers will experience similar flamespread provided there is sufficient oxygen replenishment within the pipeline.

CONSEQUENCES OF FIRES

The explosions, which apparently resulted from industrial solvents in the Louisville, Kentucky sewerage system, caused tremendous damage to the streets and sewers of that city. Fires are generally less dramatic than explosions, but can cause wholesale destruction of a pipeline, injury and loss of life. Aside from the obvious danger to people from flames during a pipeline fire, there exists the risk of exposure to asphyxiating or toxic atmospheres. The most common product of combustion is carbon monoxide, a gas that is highly toxic in concentrations as low as 0.1 percent by volume. In addition, plastic and metal pipe under flame may give off poisonous gases and fumes, such as zinc oxide, aluminum oxide and hydrogen chloride. Countless deaths have occurred during building fires when the burning contents of the building have emitted toxic gases.

A secondary consequence of fires, which must be considered, is the impact on serviceability of the pipeline. Serviceability is defined as the capacity of the pipeline to serve the purpose for which it was installed for its full design life, and includes considerations of corrosion, abrasion, flow capacity and structural integrity. Fires in concrete pipe generally do not affect structural strength, flow capacity, or corrosion and abrasion resistance. Metal pipe is usually lined and coated to forestall electrolytic and galvanic corrosion of the pipe wall and to improve hydraulic characteristics. These coatings, which are commonly composed of asphalt, coal tar,

bitumen or plastic, will flow and burn when exposed to fire. The intense heat can also alter the properties of the metal, and result in deflection and loss of structural integrity. Deflection and loss of the lining reduces the flow capacity of the pipeline which can result in flooding and property damage. Plastic pipe will suffer the same fate as metal, or worse, if the pipe melts and collapses.



Tunnel for fire testing at the Hardwood Ply wood Manufacturers Association.

LABORATORY FIRE TESTS

To evaluate the relative performance of various pipe materials, the American Concrete Pipe Association contracted with the Hardwood Plywood Manufacturers Association, HPMA, to test various pipe materials in accordance with accepted standards. HPMA's Reston, Virginia laboratory is accredited for fire testing by the International Conference of Building Officials, the Southern Building Code Congress and the Building Officials Conference of America. This laboratory regularly performs a wide range of fire tests designed to rate different building materials for susceptibility to flamespread, smoke generation and toxicity.

Testing was conducted in accordance with ANSI/ASTM Standard E84, "Test Method for Surface Burning Characteristics of Building Materials." The purpose was to determine the relative performance of the test materials under standardized fire exposure with results presented as amount of flamespread and smoke developed. Standard E 84 states:

Table 1.

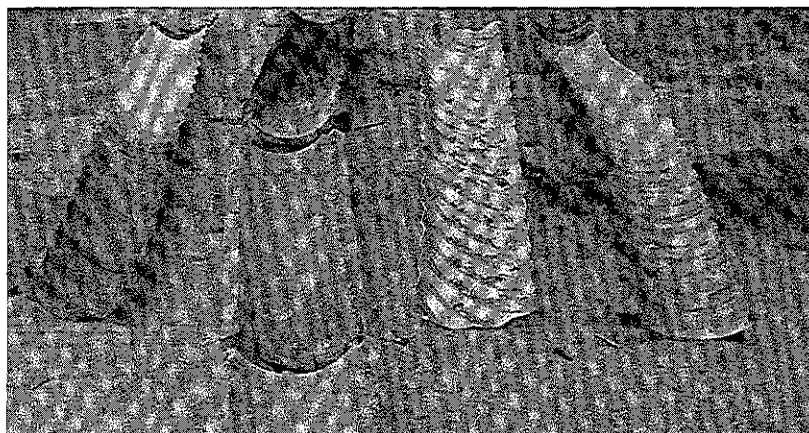
	Reinforced Concrete Pipe	Corrugated Steel Pipe With Asphalt Lining & Coating	Corrugated Steel Pipe With Polymeric Lining & Coating	Corrugated Aluminum Pipe	Ribbed PVC Sewer Pipe	PVC Sewer Pipe	ABS Composite Pipe	Ribbed Polyethylene Pipe
Wall Thickness	2"	0.064"	0.064"	0.064"	Base = 0.16" Rib Height = 0.72"	0.36"	0.127"*	Base = 0.20" Rib Height = 1.50"
Coating Type	-	• Hot Dip Galvanizing Interior & Exterior • Asphalt Interior & Exterior	• Hot Dip Galvanizing Interior & Exterior • Polyvinyl Chloride (PVC) Interior & Exterior	-	-	-	-	-
Coating Thickness	-	• 2 Ounces Galvanizing per Sq. Ft. Total Both Surfaces • 60 Mils Asphalt Over Crest of Corrugations	• 2 Ounces Galvanizing per Sq. Ft. Total Both Surfaces • 10 Mils PVC On Both Sides	-	-	-	-	-
Product Standard	ASTM C76	AASHTO M190	AASHTO M245	AASHTO M196	none	ASTM D3034	ASTM D2690	none

*Combined thickness of inner and outer walls.

Summary.

PIPE MATERIAL	FLAMESPREAD VALUE	SMOKE DENSITY FACTOR	NFPA CLASSIFICATION
Concrete Pipe	0	0	A
Corrugated Steel Pipe with Asphalt	80	860	*
Corrugated Steel Pipe with Polymeric	35	580	*
Corrugated Aluminum Pipe	0	35	A
Ribbed PVC Sewer Pipe	10	10	A
PVC Sewer Pipe	20	330	A
ABS Composite Pipe	260	435	C
Ribbed Polyethylene Pipe	60	820	*

*Smoke Density Factor exceeded maximum value allowed by NFPA No. 101.



Test sections of (left to right) corrugated steel pipe with asphalt lining and coating, reinforced concrete pipe, corrugated aluminum pipe and corrugated steel pipe with polymeric lining and coating after removal from tunnel.

"This standard should be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire

hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an

assessment of the fire hazard of a particular end use."

The data obtained from this series of tests were the flamespread value, smoke density factor, and a description of the physical appearance of the material after the test. The flamespread and the smoke density factor are obtained by comparison to those for asbestos-cement board, rated at zero, and red oak flooring, rated at 100. Each material was also classified as defined by the National Fire Protection Association in publication NFPA No. 101, "Life Safety Code." Three classifications are used by building code officials and regulatory agencies to determine the acceptability of materials for various applications.

Class	Flamespread Value	Smoke Density Factor
A	0 to 25	0 to 450
B	26 to 75	0 to 450
C	76 to 200	0 to 450

TEST MATERIALS

The materials selected to be tested were standard stock pipe for culvert and sewer use. Wall thicknesses, coatings and linings, and manufacturing processes were in accordance with ASTM and AASHTO standards. The eight materials, detailed in Table 1, were reinforced concrete pipe, corrugated steel pipe with asphalt lining and coating, corrugated steel pipe with polymeric lining and coating, corrugated aluminum pipe, ribbed PVC pipe, PVC pipe, ABS composite pipe, and ribbed polyethylene pipe. Each sample was cut longitudinally into segments whose chords were approximately 14 inches wide. The cut sections were set end to end, concave side down, on fire bricks at 4-foot centers. It was originally intended that each sample be 25 feet long, but caution by the laboratory officials resulted in shorter lengths for the plastic pipe samples. It was determined that the fuel content of the full length plastic sample was so large that the potential existed for a flare-up beyond the capacity of the tunnel, which would endanger the lives of those in the laboratory.

TEST RESULTS

Reinforced Concrete Pipe

There was no ignition or smoke generation of the concrete during the test. Upon completion of the test and removal from the tunnel, it was observed that the first four foot section of pipe was slightly darkened and had a network of surface checking on the inside surface as a result of rapid heating. The remaining 20 feet of pipe appeared sound and no checking or spalling was apparent.

Corrugated Steel Pipe with Asphalt Lining and Coating

The asphalt on this material proved to be highly flammable, producing a flamespread value of 80 and a smoke density factor of 860. The asphalt lining and coating melted and dripped to the tunnel floor and burned long after the gas burners were shut down. All of the asphalt was consumed and the pipe sagged about 6 inches in the first section.

Currugated Steel Pipe with Polymeric Lining and Coating

The lining on this sample, a PVC formulation, ignited just 17 seconds into the test and produced a flamespread value of 35 and a smoke density factor of 580. The lining was consumed for 14 feet and scorched the remaining 10 feet.

Corrugated Aluminum Pipe

There was no ignition of the aluminum during the test, but smoke was observed, resulting in a smoke density factor of 35. The first section of pipe sagged, and several areas melted within 3 feet of the flame source.

Ribbed PVC Sewer Pipe

The PVC ignited in 52 seconds and produced a flamespread value of 10 and a smoke density factor of 10. After 2 minutes under flame, the sample was sagging to the tunnel floor in one area, and, at 5 minutes, the entire section had collapsed.

PVC Sewer Pipe

The solid wall PVC burned differently from the ribbed PVC in that it ignited more quickly and produced much more smoke. Flamespread and smoke density values were 20 and 330, respectively. This sample also collapsed to the floor after 2 minutes, 10 seconds.

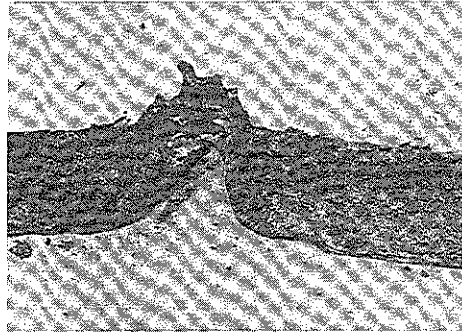
ABS Composite Pipe

This pipe material burned rapidly and totally, leaving little more than the lightweight concrete filler after

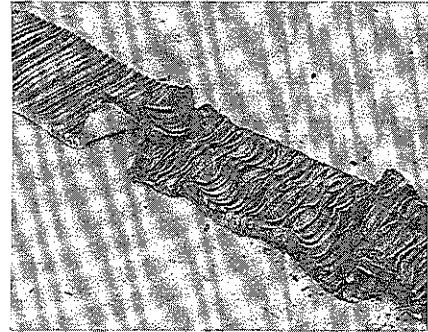
the test was completed. The high flamespread value of 260 is attributable to the tremendous fuel capacity of the ABS in this sample. Smoke density was also substantial at 435.

Ribbed Polyethylene Pipe

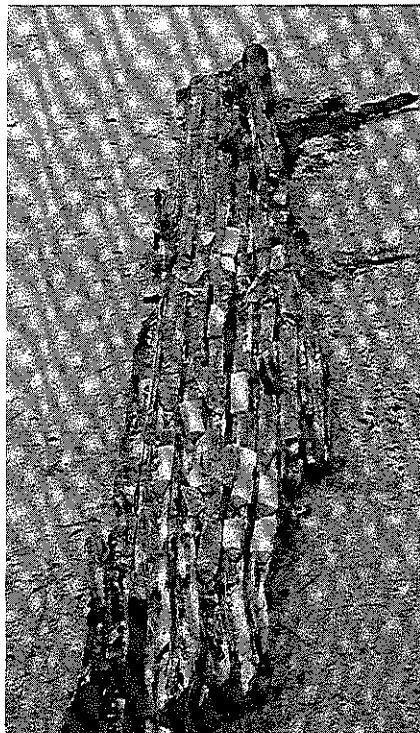
The polyethylene pipe sample was consumed totally during the tunnel test, generating a flamespread of 60 and a smoke density factor of 820. The sample lost strength and sagged to the tunnel floor where it burned long after the gas jets were closed down.



Test section of PVC pipe after testing, deformation caused by brick supporting test section.



Ribbed PVC sewer pipe test section after test was completed.



ABS composite pipe section after testing.

RECOMMENDATIONS

The susceptibility of various pipe materials to fires should be considered when planning storm sewer, sanitary sewer or culvert projects. The criterion for judging the suitability of a pipe material for buried conditions has not been established, but comparative performance under laboratory conditions can provide definitive guidelines. Because of the frequent, widespread and random occurrence of sewer and culvert fires, it is apparent project specifications should, in many instances, require fire and smoke resistant materials. This could most easily be accomplished by categorizing smoke density and toxicity in a fashion similar to that established by the National Fire Protection Association for flamespread, and specifying only those class pipe materials which provide the maximum degree of fire resistance and the minimum smoke generation. ■