Plastics Pipe

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The not-so-new kid on the block

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There is a German language expression, "Sturm und Drang," which was used to characterize a literary movement of the mid 1800s that was filled with "storm and stress." Novels in the Sturm und Drang mode contained rousing action and high emotionalism surrounding the people who dared to overturn the established order.

In the modern era, the term could be used to describe the response to the entry of thermoplastics[1] into the field of engineered piping products.

Much teeth gnashing accompanied the emergence of the thermoplastics piping industry. The pipe's qualities of durability, resistance to corrosion, ease of installation and maintenance, good flow, strength, and comparatively low life cycle costs won it important shares of the marketplace almost immediately. But this threatened many established orders, whose vociferous response forced the fledgling industry to unite, and to take coordinated action to ensure its continued vitality. Over the years, every aspect of plastics piping has been called into question: its physical and mechanical properties, its combustibility, leachability of toxic substances, and so forth. And for the past 30 years, the plastics pipe industry has met its commitment to quality and technical development.

Progress in Standardization

Over the years the plastics pipe industry has given its strong support to consensus standards writing organizations, where it works cooperatively with representatives of user, engineering, and general interest groups. The result of these efforts is evidenced by **Volume 08.04,** *Plastic Pipe and Building* **Products,** of the *1987 Annual Book of ASTM* **Standards**. Over two-thirds of the documents in this volume deal with some aspect of thermoplastics piping: 52 pipe, tubing, fittings, and other product specifications; 28 product specifications for specific applications, such as natural gas and sewer; 15 on methods of testing for physical and engineering properties and for quality control and assurance; 13 joining and installation practices; 12 on joints and joining materials; eight pipe material specifications; and four standards covering terms and dimensions. These documents are the product of the over 375 member strong Committee F-17 on Plastic Piping Systems, one of the most active and productive

of all ASTM committees. Currently, there are about 110 projects in F-17 that are directed at either revising existing standards or developing new ones in response to continually evolving product lines and technology.

While F-17 is the major source of plastics pipe standards in North America, other organizations are also involved: the Canadian Standards Assn. (CSA), Underwriters Laboratories (UL), the American Water Works Assn. (AWWA), the American Petroleum Institute (API), and the American Society of Agricultural Engineers (ASAE).[2]

In addition, the many safety, engineering, building, and plumbing codes that cover thermoplastics piping help form the foundation of its hard won acceptance for performance demanding applications.

Several trade associations contribute to the development of essential information on plastics piping, including design and installation reports, manuals, and educational programs. These include the Uni-Bell PVC Pipe Assn. of Dallas, TX; the Plastic Pipe and Fittings Assn. (PPFA) of Glen Ellyn, IL; the Plastics Pipe Institute (PPI) of New York, NY; and a division of the Society of the Plastics Industry, Inc., and its subgroup, the Hydrostatic Stress Board (HSB). The HSB was created to review data and issue recommendations of long-term strength for plastic materials intended for pressure piping applications. HSB listings have become the unofficial imprimatur for the acceptance of materials for pressure piping, and are referenced by ASTM standards.

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Still the New Kid

According to a recently issued report,[3] approximately 80 percent of the newly installed mains and 90 percent of the services for gas distribution in 1984 and 1985 were made of thermoplastics, primarily polyethylene (PE). Uni-Bell estimates that PVC accounts for over 85 percent of the sewer collection mains, sizes 4 through 15 in. (10.16 through 38.10 cm), currently installed in North America. That organization also estimates that for current installations in water distribution, over 90 percent of rural mains, and over 40 percent of municipal mains, in sizes through 12 in. (30.48 cm), are made of PVC. PPFA reports that about 80 percent of new single family dwellings include either PVC or acrylonitrile-butadiene-styrene (ABS) drain, waste, and vent (DWV) piping. And, according to PPFA, a similar market share is held by plastics for underground building/sewer connections. Most drainage systems, including those for building foundations, leaching fields, agriculture, and road construction, are now built using thermoplastics piping. Plastics pipe also holds a significant and growing market share in below ground ducting and above ground conduit for power and communications wiring, hot/cold water piping, water service connections, and irrigation. Superior chemical resistance often makes it th piping of choice for industrial applications.

The diversity of fittings, appurtenances, pipe wall constructions, and sizes that are available has grown yearly. Currently, thermoplastics pipe comes in diameters from as small as 1/8 in. (.32 cm) to as large as 120 in. (304.8 cm). Solid walled pipe for pressure and nonpressure uses is manufactured in sizes up to 54 in. (137.16 cm) for PE and 36 in. (91.44 cm) for PVC. Spiral winding processes are used to manufacture hollow profile wall pipe for sewer and drainage in sizes through 120 in. (304.8 cm). The ribs in this pipe enhance stiffness. Another technique for wall stiffening is the simultaneous extrusion of two pipes, a smooth pipe inside a corrugated one, which are then fused to form a single integral structure.

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The larger sizes are relative newcomers. The positive performance history achieved with the smaller pipes is creating a faster growing demand for the larger ones. They are expected to account for the majority of future growth for plastic piping. Principal applications for the larger diameters include water mains, sewers, and the rehabilitation of sewers, gas, and other pipelines through the sliplining process.

Back in 1955, when the first ASTM group on plastics pipe standards writing was organized, total U.S. shipments were estimated at under 40 million pounds. In comparison, *Modern Plastics* estimates[4] that for 1986, U.S. shipments totaled almost 4 billion pounds, a hundredfold increase. Within one generation, plastics piping has grown from a "new kid on the block" status to an eminent position in the industry.

"Plasticurgy"

"We turned metallurgists into plasticurgists," one industry observer recently remarked concerning the transformation of the gas distribution sector. The previously cited AGA survey includes the following observations.

- Plastic piping materials continue to provide excellent service.
- The leaks per mile of main and service for plastic pipe and (the currently used alternative) wrapped steel piping are similar.
- Plastic installation costs are usually lower than the cost of a similar installation of wrapped steel.
- Plastic piping continues to gain both in range of sizes being employed and quantities installed.

The report also states that the use of plastics for underground piping has eliminated corrosion as a cause of pipe leaks. This is very important for gas distribution and other buried pipe applications, since the insidious process of corrosion in metal pipelines disrupts service, causes l ss of product, involves expensive maintenance, over design,

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and, in some cases, jeopardizes safety.

With regard to the water distribution industry, the University of California at Berkeley recently issued a research report[5] on the results of a plastic pipe study sponsored by the AWWA Research Foundation. The report concludes that among the respondents, a high degree of satisfaction exists with PVC mains, similar to that expressed for iron, steel, and concrete, and greater than with asbestos cement.

Plastic pipe for sewer service connections and collections systems has also met with great satisfaction. Plastics' immunity to sulfide corrosion, and the systems' bottle-tight joints, which minimize sewer treatment plant loading by infiltration of groundwater, mean minimal maintenance and treatment costs.

Whenever materials or installation problems related to the use of plastics are identified, they are usually addressed and corrected by the industry, consumers, and general interests working in unison. ASTM F-17, as well as other standards and code bodies, has responded promptly, and has kept the evolution of plastic piping as an engineering material on an upward course.

Watching the Performance

It is important to recognize that, as a consequence of their viscoelastic nature, the performance properties of plastics differ in many ways from those of metals and other pipe materials. Standards, practices, and regulations call for material selection, product and system design, and installation methods that take these differences into full account.

For pressure piping, the key parameter is the long-term performance of a particular composition. This depends not only on the class of plastic material, such as PE or PVC, but also on its specific chemical architecture (molecular weight, molecular weight distribution, branching, copolymer), and the additives used (stabilizers, lubricants, modifiers, colorants).

PPI's Hydrostatic Stress Board issues a public list of recommended hydrostatic design bases (HDBs) for only those commercial thermoplastics pipe materials that have "passed muster."[6] PPI's *Technical Report 3*, "Policies and Procedures for Developing Recommended Hydrostatic Design Stresses for Thermoplastic Pipe Materials," guides the process, and augments the basic requirements of ASTM D 1598, Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure, and D 2837, Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials. The *TR-3* policies call for sufficient supplementary information, in the form of other test data and experience, to give reasonable assurance of the validity and applicability of the assumptions and extrapolating procedures inherent in these ASTM methods. PPI recommendations for long-term strength and maximum hydrostatic design stresses are listed in *TR-4*, "Recommended Hydrostatic Strengths and Design Stresses for Thermoplastic Pipe and Fittings Compounds."

Earlier this year, PPI issued *TR-2*, "Policies and Procedures for the Listing of Thermoplastic Pipe, Fitting and Fixture Materials When Evaluated Under Constant Internal Pressure With Flow Test Method (ASTM F 948)." The policy and test method combined cover the evaluation of materials under conditions of flow and temperature differential. These are more akin to actual field conditions, such as with piping used to convey hot or cold liquids.

No Grandfathers

With respect to safety and environmental concerns, plastics, unlike their metal counterparts that have been "grandfathered" into plumbing and other codes, must meet strict requirements. For example, each thermoplastic pipe material composition intended for conveying potable water must demonstrate, through testing and evaluation of its formulations by experts, that it poses no risk of leaching potentially toxic substances into the drinking water. These requirements were first established in the early 1960s, by the National Sanitation Foundation (NSF), and included in its periodically updated NSF Standard 14, Plastic Piping Components and Related Materials. Every ASTM and other standard that covers a product, including solvent cements and gaskets, that could come in contact with potable water includes a note referencing this standard. Also, every major regulation and code covering such products requires NSF approval or the equivalent.

But is it strong enough?

The potential user is sometimes concerned about plastics' lower strength and stiffness. Misinformation abounds to persuade that unyielding rigidity is the assurance of a pipe's resistance to loads due to earth, traffic, and freeze-thaw action. The argument plays on a misperception that grew out of the years of use of only rigid, but relatively brittle, materials: that plastics material is not sufficiently strong and rigid to survive ground load induced deformations.

The fact is that plastic, while more flexible, is more ductile and supple than traditional materials. A deformation induced by ground loads may deform plastics pipe, but it will not crack it. Whereas the key criterion for safe design of strong, but brittle-like pipe is avoidance of material rupture or cracking, plastic is delimited only by excessive deformation. Certainly, the idea that "stronger is better" has been undone time and again by examples of the benefits of flexible structures. Yet, despite all the research, standards review, and field-proven evidence of its performance capacity, some ads still depict thermoplastics pipe as a bent drinking straw.

But is it really safe?

Slowly, but surely, the "not strong enough" bugaboo is being erased, and supplanted by design and engineering concepts that recognize th flexible nature of plastics. A bigger frustration to plastic piping's progress is the innuendo that these products might present some unpredictable hazards to worker or public health and safety. A case in point is the never ending plumbing pipe saga in California. In the late 1970s and the early 1980s, the International Association of Plumbing and Mechanical Officials (IAPMO) made changes in its Uniform Plumbing Code (UPC) to allow expanded use of plastic pipe for DWV applications and for interior water piping. The California Housing and Development Commission was about to approve the changes to the UPC when various groups said that an "Environmental Impact Report" (EIR) on this proposed change was required under state law. The plastics industry, wishing to settle the controversy, agreed to go through with the EIR process. But the wheels of bureaucracy turn slowly, and the EIR is still not yet completed.

H wever, a preliminary Environmental Review Document was prepared by an outside consultant to the state.[7] It thoroughly reviewed all of the scientific evidence available on health and safety effects related to the expanded use of plastics pipe. No evidence was found that any particular risk would be posed. This preliminary report concludes that no environmental preference exists between plastics pipe and its metal competit rs.

Because of delays in completing the California EIR, the Vinyl Institute, a division of the Society of the Plastics Industry, commissioned a nationally recognized environmental testing laboratory to conduct a series of leachate tests on CPVC, a form of PVC used for hot water pipe, and on copper tubing with lead/tin solder joints. These tests were conducted in accordance with the protocol that had been developed by California for use in the EIR, and designed with input from the industry and other interests. The test results[8] revealed that no carcinogens or highly toxic substances were continuously leached from the plastic pipe. There was some continual leaching of metallic ions from the other products. However, the researchers concluded that overall, both systems were safe, with plastics having the lower risk.

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Other issues that are to be addressed by the California EIR include:

Worker Health—There are claims that the solvent cement used to join plastics pipe is harmful. In 1984, the National Institute of Occupational Safety and Health (NIOSH) conducted extensive tests to evaluate the potential worker health hazards. After studying actual workplace conditions, NIOSH concluded that exposure levels for individual solvent vapors were 20 percent or less of the Occupational Safety and Health Administration (OSHA) or other applicable maximum exposure level. It was concluded that workers could be adequately protected from any possible adverse effects by sensible workplace practices. Furthermore, evaluation of statistics on relative hazards show that injuries from working with heavier metal pipe are substantial.

Permeation—It has been alleged that plastics piping systems used for potable water are vulnerable to permeation through the pipe walls of organic chemicals that might be present in contaminated soil.

In those few instances where permeation has been found, it has involved plastics pipe exposed to soils grossly contaminated by leaking underground gasoline storage tanks, or some other persistent source. In all such cases, the extent of ground contamination alone was severe enough to constitute an environmental hazard. A study by Battelle Memorial Institute[9] found little serious soil contamination in the United States. In another study,[10] Battelle determined that in a seriously contaminated soil, permeation can occur not only through plastic pipe walls, but also through gaskets and packings. Because of this, the AWWA has issued a permeation statement to be incorporated in the body of all its appropriate standards, metal as well as

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plastic. This statement advises that if a pipe must pass through an area subject to present or future contamination by organics, the manufacturer sh uld be consulted regarding permeation of pipe walls, jointing, and the like, before selecting materials for use in that area.

Fire—Because plastics are combustible, it has been alleged that installation of plastics pipe poses a fire safety risk and, therefore, should be banned.

The plastics industry's position is that combustibility should be treated by regulations through building codes, not by a total ban. Plastics pipe represents a very small portion of the total amount of combustibles found in a typical, non-fire rated building. Furthermore, plumbing in such buildings is encased in fire resistant panels. Therefore, these products are not likely to become involved until the combustion of other materials has already created a serious fire. It has been estimated, for example, that over one million DWV systems made from ABS materials have been installed in California in non-fire rated buildings; there is no evidence that they have contributed to increased fire risks.

In fire rated structures, certain construction principles,[11] such as the use of fire resistive walls and fire stops, must be followed to ensure that basic fire resistivity is not compromised.

Fussin' and Feudin'

When the dust periodically settles in the "great pipe debate," and the "Type A" personalities go back to their corners, the secret weapon of the plastics pipe industry becomes more apparent—its patient trust in the consensus standards system. It seems that the fussin' and feudin' cuts both ways these days, and some of the "grandfathered" pipe materials are getting the same scrutiny they demand for plastics. For example, under the Bradley-Lautenberg "lead-free drinking water" amendment, a part of the recent Safe Drinking Water Act, states must prohibit lead pipes and lead based solder in all new construction or repair of public water systems. And, recently, the U.S. Environmental Protection Agency (EPA) announced the selection of a consortium headed by the National Science Foundation (NSF), and including the AWWA Research Foundation, and the Council of State Health and Environmental Managers (COSHEM), to develop a system for evaluating all products, not only plastics, that may come in contact with potable water to ensure water quality during treatment, storage, and distribution. The goal is to have an Indirect Additives Program, which can be used to regulate the substances that could enter the wat r supply by leaching, extractions, or corrosion from piping and other equipment, in place by the summer of 1988.

Cooperation

Plastic piping was born and raised under careful scrutiny. The industry has been case hardened, but remains surprisingly resilient. It responded in good faith to problems that arose from time to time, and forged an excellent reputation in many performance conscious applications.

This background of experience, the advanced state of the art attained over a generation, improvements in materials and processing, and the growing acceptance of plastics as an engineering material portend an exciting future.

Though controversy seems to be a c nstant companion, the plastics pipe industry does not consider itself an adversary of other engineering materials. On the contrary, it has added to the intelligent choices that can be made from among the many materials available to the consumer.

References

[1]Only thermoplastics, the term covering plastics that can be reshaped through heating, including polyethylene (PE), polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC), polybutylene (PB), and polypropylene (PP), are covered in this article. For purposes of this report, plastic and thermoplastic are used interchangeably.

[2]The Plastics Pipe Institute (PPI) issues a listing of all current standards in its *Technical Report 5*, "Standards for Plastics Piping."

[3]"American Gas Association Plastic Pipe Assessment Update," by Theodore J. Zabel, presented at AGA Distribution/Transmission Conference, May 4-6, 1987.

[4]*Modern Plastics*, January 1987.

[5]"Review of Water Industry Plastic Pipe Practices," by C. Thompson and D. Jenkins, Department of Civil Engineering, University of California, Berkeley, CA, American Water Works Association Research Foundation Report No. 90516.

[6]The hydrostatic design basis is the long-term failure stress value of a plastic material that has been categorized into one of an established set of (preferred) stress values.

[7]"Environmental Review of Proposed Expanded Uses of Plastics Plumbing Pipe," by SRI International, March 1983, prepared for the State of California Department of Housing and Community Development.

[8]"Effects on Water Quality by Leachable Substances from Copper Tubing, CPVC Piping and Galvanized Pipe Fittings," by McKesson Environmental Services, Inc., May 1986.

[9]"Literature Study of Low Contaminant Levels of Organics in Soils and of Their Potential for Permeation through Plastic Pipe," Battelle Columbus Lab., 1985.

[10]"Evaluation of the Permeation of Organic Solvents Through Gasketed Jointed and Unjointed Poly(Vinyl Chloride), Asbestos Cement and Ductile Iron Water Pipes," Battelle Columbus Labs. 1983.

[11]See "Plastic Pipe in Fire Resistive Constructions," the Plastic Pipe and Fittings Assn., Glen Ellyn, IL.