THE ROLE OF
PLASTIC PIPE
IN COMMUNITY WATER SUPPLIES IN DEVELOPING COUNTRIES

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A Report By

Frederick E. McJunkin and Charles S. Pineo

Department of Environmental Sciences and Engineering
School of Public Health
University of North Carolina
Chapel Hill, North Carolina

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I

SUMMARY AND RECOMMENDATIONS

Introduction

Fundamental premises of the AID-WHO global community water supply program in developing countries are that water should be treated as a commodity, that water systems should be managed on a businesslike basis and essentially pay their own way, and that the present level of building new systems and strengthening and extending existing systems needs to be greatly expanded in order to overcome present backlogs and keep pace with urban growth.*

Since there is little evidence of present over-capacity of production within the developing countries themselves of the basic or finished materials which go into the construction of urban water supply systems, and none whatever when regional trade needs are taken into account, the foregoing premises collectively suggest the need for expanding these production capacities within the utilizing areas. Such expanded production capacity should be centered on those components of water supply systems which make up the greater part of the materials and equipment elements of construction cost. Expanded international trade between the more highly industrialized countries and developing countries arising from expanded rates of water supply development in the latter would tend to be concentrated on the more specialized and complicated materials and equipment items and on items only occasionally required or used only in small quantities.

The alternative to this concept would be for these expanded needs to be met entirely rather than only partly, by increased imports from the more industrialized areas of the world. This alternative is difficult to rationalize either with the introductory fundamental premises or with the realities of international finance and trade economics.

That the major portion of urban U.S. water supply construction costs consists of non-labor items (materials, installed equipment, construction

*For background see McJunkin, Frederick E., "Community Water Supply in Developing Countries: A Quarter Century of United States Assistance," AID, 95 pp., 1969, and U.S. Public Health Service, "Guidelines and Criteria for Community Water Supplies in the Developing Countries," 101 pp., 1969.

equipment, etc.) is well-known. High wage rates are offset in part by extensive use of labor-saving equipment, especially in earthwork and pipe installations. Although the ratio of non-labor to labor costs in water supply varies from country to country as well as for different elements of water systems, non-labor project-site costs also represent most of the cost of urban piped water supply construction in developing countries as a group, as well as in the U.S.A. In fact, for those job items which require non-skilled labor using the ordinary tools of the trade, labor costs in other countries usually comprise a smaller proportion of total project cost than in the U.S.A.

This means, simply, that materials and equipment produced within the individual countries of regions must be utilized in urban water supply construction if major savings in hard currency requirements are to be realized by consuming and lending countries.

Secondly, it means that these materials must be important elements of the construction cost breakdown if the impact of this contribution is to amount to much.

This line of reasoning invites attention to pipe, since pipe of one type or another usually is the most important single non-labor cost item in water supply construction. In the case of new systems, for example, the distribution system usually is more expensive than treatment plant and source of supply development. Furthermore, pipe used in treatment plants, wells and transmission lines is always a significant element and can be the principal element in the combined costs of treatment plant and source of supply development.

The significance of pipe as a cost element is obviously more variable where improvements to existing urban water systems are involved. Most projects of this type require individual analysis, with the proportionate cost of pipe ranging from very minor to almost all of the non-labor project costs. However, by far the commonest type of improvement is the extension of distribution systems.

The proportionate cost of pipe to the total non-labor cost of such systems is substantially higher, on average, in developing countries than in the U.S.A. In the U.S.A., for example, the cost of valves, fittings, and hydrants can vary from 5 percent to about 35 percent of the total cost of distribution system grids, exclusive of elevated storage. A "typical" system in a developing country tends to require more limited investment in these components, including elevated storage. Primarily this is due to lower fire-flow values or no provision for fire flow, with consequent reduction in elevated storage, fire hydrants and in distribution system grids with their valve and fittings requirements.

At present, the choice of pipe materials overseas in the larger sizes of street mains (4-inch and larger) in community water supply systems lies between cast-iron and asbestos-cement pipe, with use of cast-iron pipe generally predominating. Some plastic pipe is manufactured in diameters up to 8-inch, and infrequently, 12-inch. In the smaller sizes of street mains and in house connection lines and house supply systems (1/4-inch to 3-inch), galvanized steel pipe predominates with plastic pipe developing as a competitive product. Copper pipe is occasionally competitive. These size classifications are somewhat arbitrary since cast-iron pressure pipe is known to be made in dimensions down to 2-inch and asbestos-cement pipe down to 1 1/2-inch, while both galvanized steel and plastic pipe of some types are made in 6-inch diameters or larger.

In some areas the cost of plastic pipe is as low as half that of galvanized iron in small diameters. With 1.5 billion people to be served, even pennies per foot represents millions of dollars (or millions more people served). Unfortunately, these savings are not always realized since a high-profit, low-volume philosophy prevails in many foreign countries. In some others monopolistic pricing destroys the cost differential.

The cost of bathrooms and of house connection lines in post-war U.S. houses probably equals or exceeds the residential customer's share in the combined construction cost of public water and sewerage systems. This statement is probably true even when only residential plumbing costs are considered in the comparison (i.e., structure cost excluded).

In developing countries, the proportionate cost of plumbing fixtures and house connection lines in the simplest type of residential service in urban water systems is obviously very much less (such as where service is limited to a yard faucet or porch faucet services with no sewerage) and materials logistics and economic cost considerations are almost entirely limited to prospects for substituting plastic pipe for metal pipe. However, the extent to which bathroom facilities are provided and their cost relative to per capita income and to the cost of public water supplies can vary widely by size of city and in different areas of a city in many developing countries. This situation suggests that the cost of piping and fixtures involved in supplying water from the street main and in water use and disposal within the premises occasionally can exceed that of the public property lines in water supply logistics and financing.

Pipe is a major cost element of community and household water systems. In the most common diameters pipe made of plastics is competitive in cost and performance, and in many circumstances, costs less than pipe of other material. Plastic pressure pipe can be readily manufactured in developing countries with a minimum of hard-currency capital investment, skilled labor relative to other forms of pipe, and expenditure for imported materials, relative to production of other pipe.

Organization of Report

The basic intent of the report was preparation of a document, complete in itself, which would enable engineers, administrators, public officials, industrialists, personnel from AID, WHO-PAHO, the international banks, and others to review the role of plastic pipe in community water supply in developing countries, and further, to provide a resource document to support further technical or administrative action. In order to serve such a wide clientele and to keep the required reading effort within manageable proportions, extensive use has been made of specialized appendices. The text, combined with the appendices, should enable the reader to (1) weigh the merits of plastic as a pipe material, (2) quickly acquire an awareness of the state of the art, (3) prepare design criteria and standards and specifications for manufacture, testing, and installation of plastic pipe, (4) organize a testing program, and (5) undertake preliminary feasibility studies of manufacture and marketing of plastic pipe.

The supplemental role of the appendices may be ascertained from the following brief descriptions.

Appendix A: "Abbreviations." A dictionary of the more often used abbreviations in the text and appendices. All abbreviations are defined when first used. Also see Appendix D.

Appendix B: "Bibliography." Contains complete bibliographic citations to all authorities specifically mentioned in the report plus general references and the majority of published documents relevant to the topic at hand. Over 120 references.

Appendix C: "Standards and Specifications for Plastic Pipes." A list of all major U.S. standards and specifications (over 120) relevant to plastic pressure pipe plus numerous (over 30) foreign ones.

Appendix D: "A Glossary of Plastic Piping Terms." Plastic pipe has its own technical vocabulary, much of which is new to the waterworks industry and to some readers of this report. This appendix should provide a working vocabulary for those officials and engineers with new responsibilities or interest in plastic pipe.

Appendix E: "Other Information Sources." A listing of further sources of general and technical information on plastic pipe. Also an extensive listing and description of resources available for overseas assistance to U.S. business.

Appendix F: "Directory of Manufacturers." A listing of U.S. manufacturers and suppliers of plastic materials, plastic pipe and fittings, and production machinery who supply the water supply industry.

Appendix G: "NSF Std. No. 14 for Thermoplastic Materials, Pipe, Fittings, Valves, Traps, and Joining Materials." Excerpts.

Appendix H: "Installation of Plastics Pipe." A manual.

Appendix I: "Plastic Pipe for Sewers" and *Appendix J:* "Plastic Pipe for Gas Service." Brief descriptions of two products that are readily produced with same plant required for pressure pipe for water service.

Conclusions and Recommendations

1. Plastic pipe is already a successful material as evidenced by its widespread use in the U.S., Europe, and Japan and limited use in Latin America.

2. Plastic pipe offers several advantages: light weight, longer length, depending on type, lower coefficient of hydraulic friction, resistance to

corrosion, *et al.* However, the principal advantage is lower cost. Savings are possible in *both* local *and* foreign currencies.

3. Properly manufactured plastic pipe poses no danger to health. Lead stabilizers are used in some European and in Japanese PVC* formulations without *apparent* ill effect, but are not used in U.S. PVC pipe for water supply. Thus, the use or non-use of lead stabilizers is a local decision, although the use of known toxic additives in pipe compounds cannot be encouraged.

4. The basic work of developing standards has already been done in the U.S. and Europe. A country using or contemplating use of plastic pipe can study existing standards and prepare standards most suitable to local conditions.

5. A quality control program is essential to successful manufacture and use of plastic pipe. This need not be expensive or complex. Expert assistance is readily available from the U.S. (e.g., the National Sanitation Foundation).

6. Plastic pipe is suitable for use in tropical conditions.

7. Plastic pipe can be readily manufactured abroad. A viable local manufacturing plant can be established with less than $100,000 invested in equipment. Raw materials, formulated for extrusion, are readily available in an extensive international trade. New or existing plants are easily expanded with growing demand.

8. Production of pipe fittings should be undertaken only by well-financed, experienced producers.

9. Potential pipe sales in the developing countries are in the hundreds of millions of dollars annually. The variation, however, in national markets is extreme. Markets for gas, sewerage, and irrigation pipe and electrical conduit should not be overlooked.

10. Shipping costs are likely to inhibit any widespread direct sale of U.S.-manufactured pipe. This is a minor factor, however, in sale of plastic compounds for extrusion.

11. The primary market for U.S. sales is in plastic compounds for extrusion. This is a global, capital-intensive industry. Sales of U.S. equipment and pipe fittings and molds offer a small, specialized market.

12. Establishment of plants for production of primary plastic materials will be limited to those developing countries with large population bases, relatively high economic development, and/or local oil resources. The

*Abbreviation of polyvinyl chloride, a plastic polymer. See Appendix D, "A Glossary of Plastic Piping Terms."

economies of scale of these plants are such that sales to pipe producers are likely to take only a minor fraction of output.

13. International agencies should adopt the technical assistance strategy outlined below. The lever of capital assistance can also be influential in local adoption of the recommended actions. These activities are not expensive and potentially may return their costs many times.

a. Encourage adoption of plastics as alternative pipe materials for public water supplies.

b. Encourage adoption of national standards for plastic pipe where none exist.

c. Encourage a national quality control program for plastic pipe.

d. Prepare, publish, and distribute a country-by-country market analysis with special attention to the more promising markets.

e. Encourage establishment of plastic pipe extrusion plants in those countries with sufficient demand as indicated by (d).

f. Encourage competitive pricing of plastic pipe.

g. Make training and demonstration opportunities available to those individuals interested in manufacturing, testing, or installing plastic pipe.

h. Provide short-term consultants to those manufacturers, testing laboratories, and water supply and construction agencies initiating use of plastic pipe. Technical help is particularly needed in the first phases to set up plants and get them operating properly.

i. Support local short courses on plastic pipe.

II

BACKGROUND OF STUDY

The Problem

Environmental deficiencies, exemplified by poor water supplies, led the list of the world's major health problems in order of importance assigned them by 90 governments reporting in the *Third Report on the World Health Situation* recently published by the World Health Organization (WHO). Although all nations have deficiencies in providing adequate supplies of potable water for domestic use, the problem is most critical among the developing countries. A 1962 WHO study of the world-wide problems of urban community water supply may still be considered representative of conditions of the 75 developing countries included. The distressing findings of this study were that, in these countries, only about one-third of the urban population and less than 10 per cent of the total population are supplied with piped water in or near their homes. Even where piped supplies exist, their safety is limited by the intermittent nature of the service and their failure to meet even minimum hygiene standards.

The existing tremendous backlog of needs for water supply is not only a serious problem in itself but is aggravated by growing population pressures. United Nations demographers predicted in 1965 that, if the present popualtion growth continues, world population will reach 7.4 billion by the year 2000, more than doubling the 3.3 billion population at the time of the prediction. Over 85 percent of the increase will be in the high birth-rate developing countries of Asia, Africa and Latin America where more than four-fifths of the world population will be living by the year 2000. The trend is even more evident in urban centers where migration is responsible for an urban population growth rate about 250 per cent that of the rate of rural growth. When it is considered that less than 10 percent of the existing developing world population are supplied with piped water, the rapidly increasing size of the problem can be appreciated.

The magnitude in monetary terms of the water supply needs is not really known. Estimates by authoritative sources range from 6 billion to 25 billion dollars as the cost of the work that urgently needs to be done. It is probably nearer the upper figure and may well be much more–in the first 50 years of this century the United States alone spent over 20 billion dollars (replacement value) on public water supplies.

With such large sums of money involved, it is self-evident that any percentage of savings however small which may be effected in materials or the design and construction of water supply systems will in itself result in overall savings which will be substantial. Waterworks materials and equipment that can be locally produced are especially desirable due to the balance-of-payments problems of most developing countries.

An analysis of the elements of a water supply system reveals that pipe is usually the single most important non-labor cost item. Although the ratio of non-labor to labor costs in water supply construction varies from country to country as well as for different elements of water systems, it is generally recognized that non-labor project-site costs represent most of the cost of urban piped water supply construction particularly in the developing countries.

In the case of new systems, the distribution system usually is more expensive than the treatment plant and source of supply development. Moreover a typical system in a developing country tends to require more investment in pipe and less in valves, fittings and hydrants primarily due to lower fire-flow values or no provision at all for fire protection. Pipe used in treatment plants and transmission lines is always a significant element and can be the principal element in the combined costs of treatment plant and source of supply development.

Because of the overall importance of pipe as an element in water supply system costs, attention is focused on the properties of plastic pipe and the contribution it can make to the water and sewerage fields in the developing countries of the world.

Plastic Pipe: Advantages and Disadvantages

Plastic pipe has been singled out for attention because of a number of physical properties which make its use advantageous from various points of view and also because it may be produced in comparatively inexpensive, uncomplicated plants, opening up the possibility of manufacturing the pipe in the developing countries, thus avoiding the importation of one of the major elements of water supply systems.

Some of the advantages of plastic pipe over pipe of traditional materials may be summarized as follows:

(1) Favorable initial and maintenance costs.

(2) Light weight resulting in lower handling and transportation costs.

(3) Longer length, depending on type, and ease of joining pipe reduce jointing costs.

(4) Lower coefficient of friction permitting greater flows through a particular pipe size.

(5) Resistance to corrosion and build-up of deposits.

(6) Good chemical resistance with non-absorbent walls.

(7) Freedom from galvanic or electrolytic action.

(8) Lower modulus of elasticity giving an advantage where there is soil movement or vibration.

(9) Good tensile strength.

(10) Thermal and electric insulator.

(11) A good combination of properties–many of which can be controlled during the manufacturing process.

As might be expected, there are also some disadvantages, actual and rumored.
Included are:

(1) Lower mechanical strength.

(2) Higher thermal expansion

(3) Being a non-conductor of electricity, it cannot be used to ground electrical equipment nor traced by electro-magnetic methods when it is buried. A plastic-coated steel tape or copper wire is sometimes attached to plastic pipe for this purpose.

(4) Sensitive to temperature, becoming brittle and difficult to handle at low termperature, and losing strength at high temperature. The temperatures are generally outside the normal ranges for public water systems.

(5) Classified as a slow-burning material–not a fire hazard. Some plastics are self-extinguishing.

(6) Rats can bite through it–but do not prefer it to other materials.

Some of these characteristics will be discussed individually before considering the types of plastic pipe most frequently used in water supply and sewerage system applications.

Favorable cost: When plastic pipe first came into general use for water supply systems it was competitive with other pipe only in the smaller sizes up to about 2-inch diameter. With the decrease in costs of the basic materials (resins) and the increase in the cost of other pipe materials, plastic pipe is now competitive up to 12 inches in diameter, particularly when installation costs are taken into consideration.

Installed costs of various sizes of cast iron, asbestos cement and PVC plastic pipe for rural Illinois installations are compared in Figure 1. A comparative cost analysis for smaller pipe sizes is shown in Table 1 and Table 2.

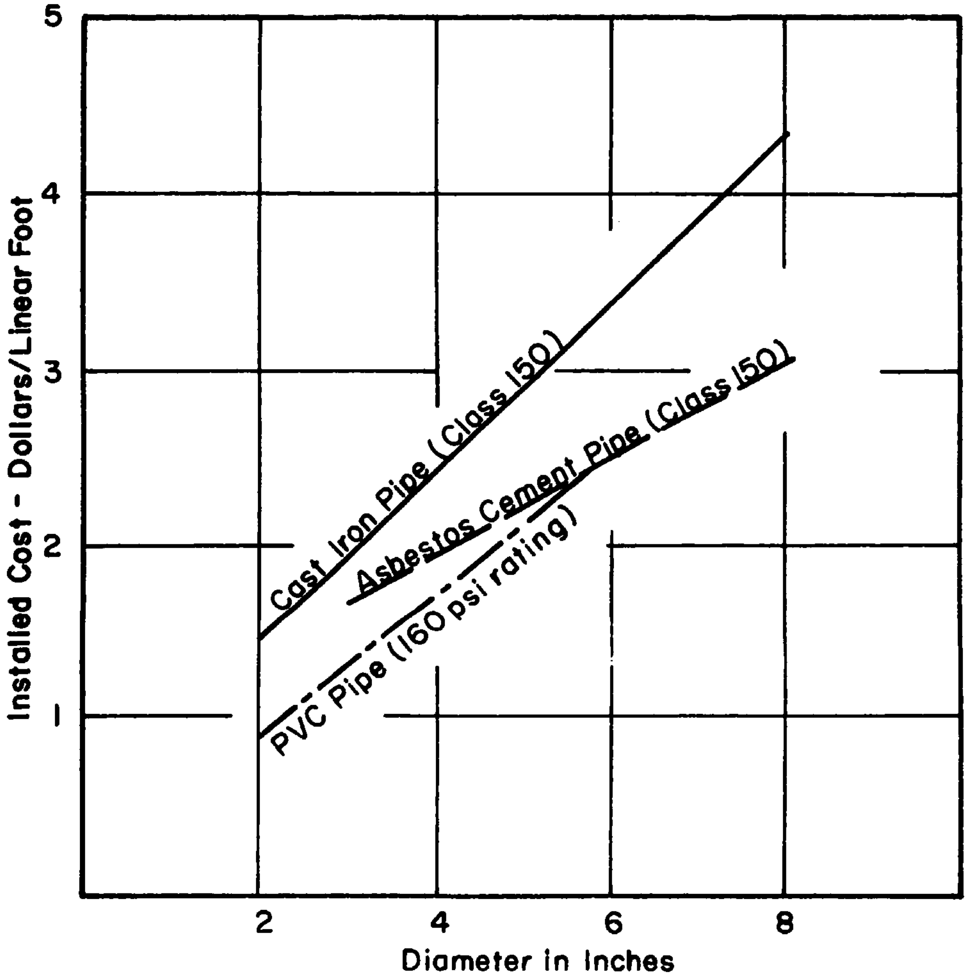

Figure 1

AVERAGE INSTALLED COSTS OF WATER MAINS IN ILLINOIS FHA PROJECTS FROM 1965 to 1968

TABLE 1

COST COMPARISON OF PLASTIC AND METAL PIPE IN DOLLARS PER LINEAR FOOT (1967)

Use And Size	Copper	Galv. Steel	PE	PVC 160
Interior Supply				
½ in.	0.26	0.18	0.05	0.11
1 in.	0.62	0.33	0.15	0.17
2 in.	1.72	0.72	0.60	0.45
Drain, Waste, Vent				
2½ in.	1.23	1.08	0.69	0.65
4 in.	2.55	2.16		1.60

Source: Pierce, Jack W. "Plastic Pipe - A Progress Report." *Civil Engineering,* Vol. 37, No. 2, pp. 61-64 (February 1967.)

TABLE 2

COST BREAKDOWN FOR DRAIN, WASTE, VENT INSTALLATION

(Labor and materials for typical one family dwelling - 1967)
California - U.S.A.

	ABS or PVC	Copper	Galv. Steel or Cast Iron
Labor			
Time (Man hours)	4¼	12	22
Cost	17.32	48.90	89.65
Materials			
Cost	97.85	114.91	115.99
Total Cost	$115.17	$163.81	$205.64

Source: Pierce, Jack W. "Plastic Pipe - A Progress Report." *Civil Engineering,* Vol 37, No. 2, pp. 61-64 (February 1967.)

There are substantial variations in material and installation costs as illustrated by the following comparison for plastic and copper water service line installation.

TABLE 3

WATER SERVICE LINE

MATERIAL AND INSTALLATION COSTS FOR PLASTIC AND COPPER PIPE

Pipe Dia. (in)	Material Costs				Installation Costs			
	Plastic Pipe		Copper Pipe		Plastic Pipe		Copper Pipe	
	Lowest Cost	Highest Cost	Lowest Cost	Highest Cost	Lowest Cost	Highest Cost	Lowest Cost	Highest Cost
	Dollars per foot				Dollars per installation			
¾	0.12	0.22	0.47	0.62	30.00	58.69	26.00	38.75
1	0.20	0.33	0.57	0.60	37.00	57.29	37.00	56.16
1½	0.31		1.00		89.00*		100.0*	
2	0.50		1.51		156.00*		150.00*	

*One utility reporting

Source: "AWWA Committee Progress Report - Plastic Pipe and Fittings." *Journal American Water Works Association,* Vol. 59, No. 10, pp. 1238-1248 (October 1967.)

As might be expected there is a rather wide spread in the prices of plastic pipe from one country to another. The data from 16 countries as reported at the Sixth Congress of the International Water Supply Association in 1964 are tabulated in Table 4. 1-inch low density PE varies from 3 cents a foot in Japan to 18 cents in Ireland with an average of 8 cents. 3-inch PVC pipe varied from 21 cents to 58 cents a foot with an average of 38 cents.

Recent prices for plastic pipe in Latin America are shown in Figure 2.

Light weight: Plastic pipe has a tremendous advantage weight-wise which is particularly important in transportation cost and ease of handling to job sites which are often remote in the developing countries. A mile of 4-inch 130 psi PVC pipe weighs 4.3 tons compared with 18 tons for asbestos cement pipe and 55 tons for cast iron. One man could easily carry two 20-foot lengths of 4-inch PVC pipe but with the same effort could carry less than 5 feet of

TABLE 4

PLASTIC PIPE IN WATER SUPPLIES

COUNTRY	Miles in Service - End of 1962			Unit Price (U.S. $/lin. ft.)		
	Polyethylene		Polyvinyl Chloride	Polyethylene		Polyvinyl Chloride
	Low Density	High Density		Low Density diam. 1"	High Density diam. 1"	diam. 3"
AUSTRALIA	930		5	0.092	-	-
BELGIUM	620	little	140	0.049	-	0.366
CZECHOSLOVAKIA	Several		Several			
DENMARK (odense only)	12		26	0.064		0.335
FRANCE	1,900		5,000	0.061	0.058	0.518
GREAT BRITAIN	80,000	3,100	5,000	0.073	0.079	0.213
HUNGARY	85		3	-	-	0.182
IRELAND	125	little	440	0.183		0.61
JAPAN	10		75	0.031	0.029	0.213
LUXEMBURG	85	3		0.092	0.072	0.488
NETHERLANDS	1,060	7,200				
POLAND	-	-	11			50% Galv. Pipe
SOUTH AFRICA	5,600		little			
SWEDEN	40,000	little	1,500	0.073		0.396 to 0.579
USA				0.065	0.093	
USSR	Tens of thousands			61% of Galv. Steel	38% of Galv. Steel	88% of Galv. Steel
WEST GERMANY	370	420	520			

Source: International Water Supply Association (1964.)
Note: Prices are for pipe only and do not include installation costs. "Density" is classified differently in U.S. than in Europe.

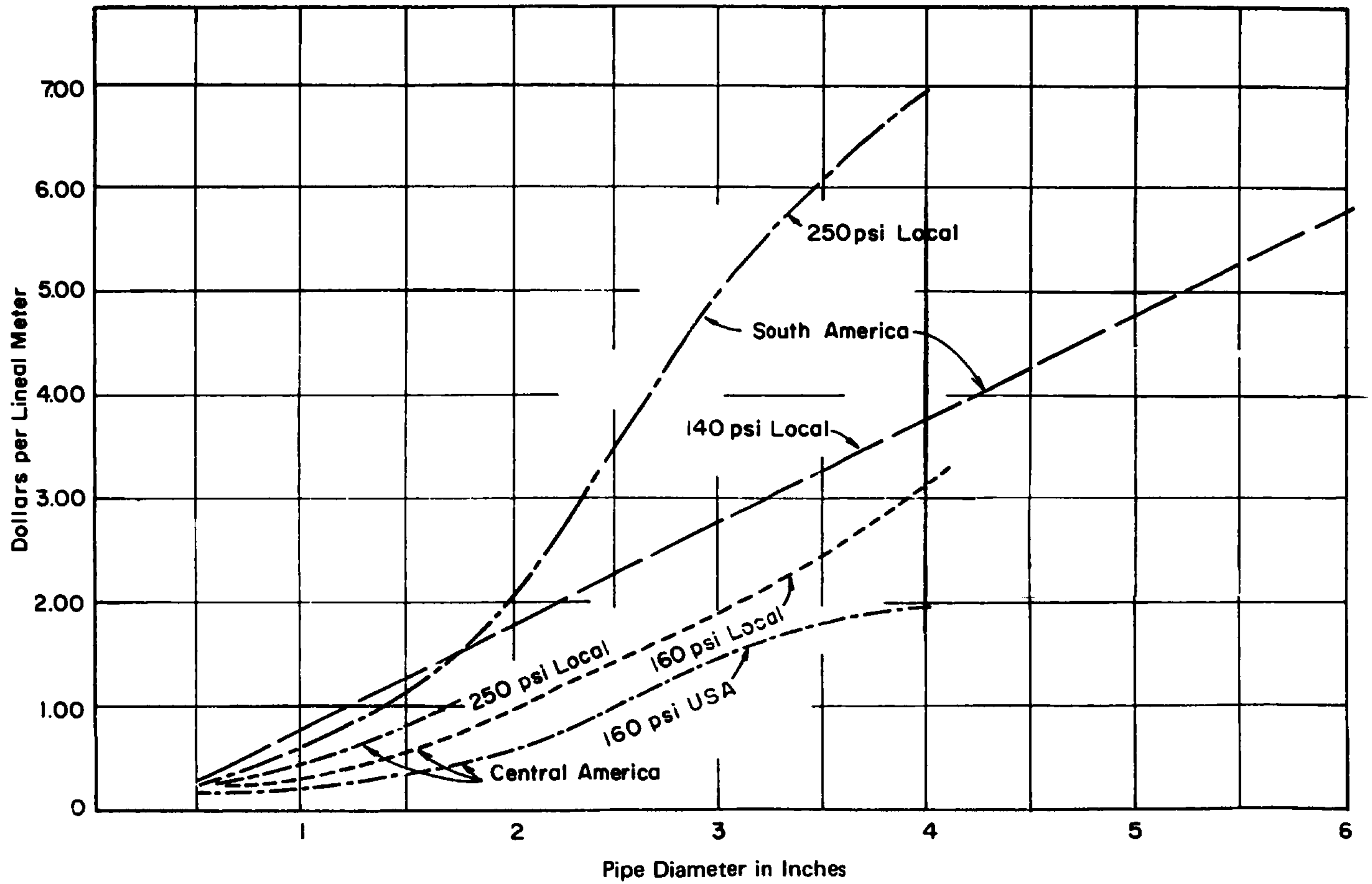

Figure 2
1968-1969
PLASTIC PIPE PRICES IN CENTRAL & SOUTH AMERICA
(Local & USA manufacture)

4-inch cast iron pipe. A 300 foot coil of 1-inch PE pipe weighs about 40 pounds. This extremely light weight makes it easier to install the plastic pipe, particularly in the larger sizes which can be installed without the use of tripods or lowering equipment. Figure 3 shows the comparative weights for a range of sizes and pressures for British Standards.

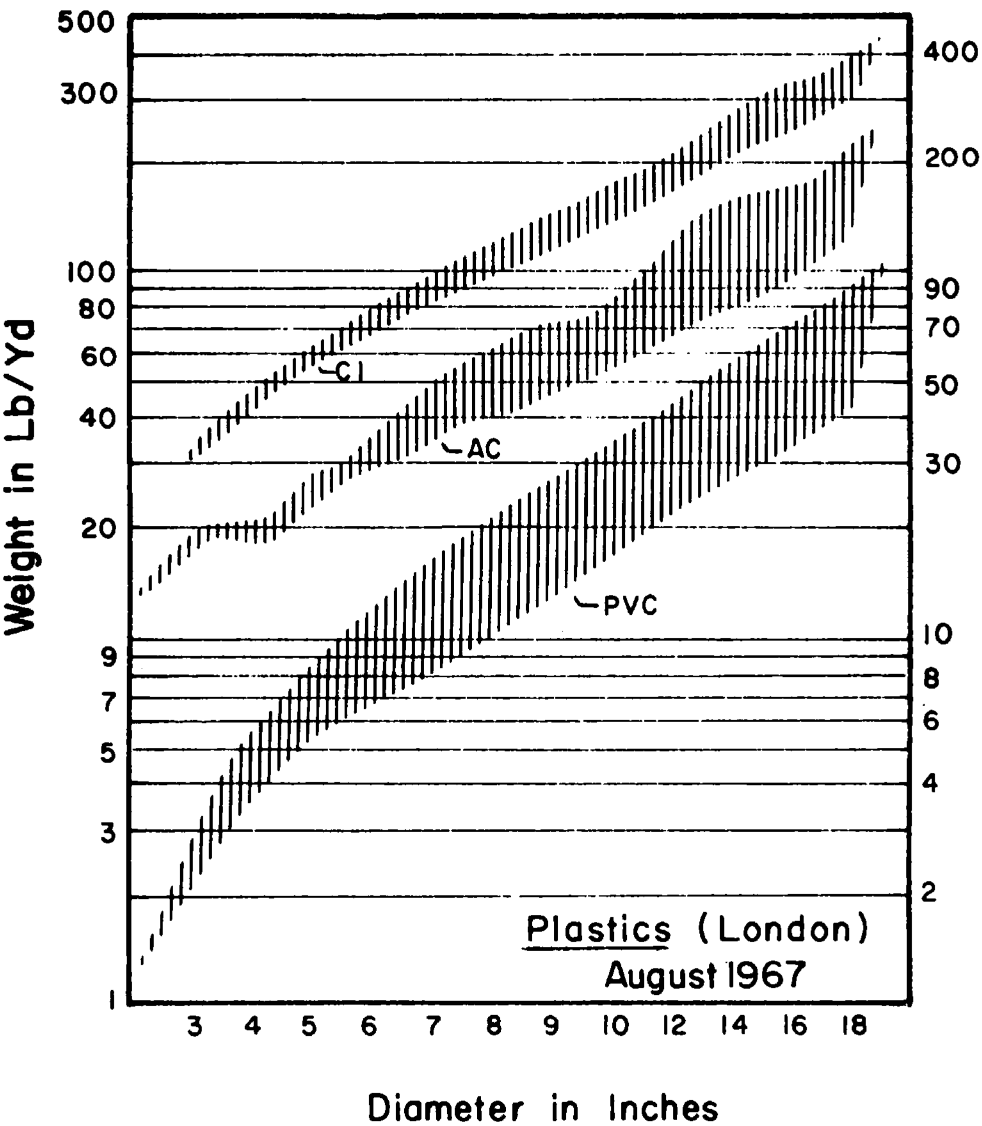

Figure 3

WEIGHT COMPARISON FOR PRESSURE PIPE IN PVC, ASBESTOS CEMENT, AND CAST IRON IN LB/YD FOR PRESSURES FROM 65 to 173 PSI

Longer lengths: PVC Type I (unplasticized) pipe comes in lengths up to 40 feet and PVC, Type II, and PE pipe can be obtained in 1500 foot coils of 3/4-inch and 200-foot coils of 2-inch pipe. This reduces the number of joints very materially from the number required on other types of pipe. Pipes may also be joined at the trench side and then lowered into the trench with ropes making it possible to use a much narrower trench. For instance, a 4-inch plastic pipe can be laid in a 6-inch trench, whereas a cast iron pipe will require from 18 to 30 inches.

Joining the ends of plastic pipe has been improved and simplified. In addition to joining the pipe by insert fittings, by flaring, by solvent cementing, or by threading (which is acceptable for some material and pipe sizes), and by mechanical joints, PVC pipe has recently been made available with a bell-end formed as an integral part of the pipe on sizes from 1 1/2 to 6-inches in diameter. A multi-ribbed rubber ring provides the seal and makes a flexible installation eliminating the need to "make" the pipe in the trench to allow for expansion and contraction. Another distinct advantage is that the joints may be handled immediately and the line can be filled, tested and placed in service immediately without waiting for solvent cement to dry.

Lower coefficient of friction: The relatively high value of "C" (150 for plastic pipe versus 120 for galvanized iron) for the Hazen-Williams formula used in calculating the flow of various types of pipe indicates the advantage in using plastic pipe because of its lower coefficient of friction. Because of its nonscaling, hydrophobic surface and resistance to corrosion and tuberculation, plastic pipe maintains its high "C" whereas the "C" of some of the other materials is reduced in time as evidenced by the very appreciable reduction between new and old unlined cast iron pipe.

Resistance to corrosion: This characteristic is important both on the inside and outside of plastic pipe. Its resistance to corrosive soils is of great value in many areas where the soil is aggressive. Long range burial tests have shown practically no effect on the plastic pipe. Experiments carried out to determine the susceptibility of plastic pipe to bacterial growth have shown that the number of bacteria adhering to the internal surfaces of plastic pipe is no greater than that adhering to other pipe. In fact disinfection experiments with very high doses of chlorine showed that plastic pipe could be disinfected comparatively better than old and new galvanized iron pipe.*

Good chemical resistance: The chemical resistance of plastics pipe varies from good for PE and ABS to excellent for PVC and CPVC. Lists are available of the effects of large numbers of reagents on plastic pipe. One list is headed by the statement that PVC has outstanding resistance to a wide range of chemical reagents in temperatures up to 140°F. Normally plastic pipe is

*N. U. Rao, R. P. Mishra, K. Subba Rao and C. S. G. Rao. "Suitability of Plastic Pipes for Conveying Drinking Water". *Environmental Health* (Nagpur), Vol. 10, pp. 68-82 (1968).

resistant to all chemicals found or used in homes but for industrial applications a special study should always be made of the short- and long-term effects of the fluid being transported. PVC pipe is being used with outstanding savings in cost and maintenance time in water treatment plants for alum solution lines, sodium silicofluoride lines, prechlorination and post-chlorination lines, and to carry carbon dioxide and highly corrosive carbon slurry.

Local Production of Plastic Pipe

The principal potential advantage of use of plastic pipe is favorable costs. In developing countries, costs have two significant components: local currency and foreign exchange. Local manufacture of plastic pipe is relatively easily and inexpensively established, in comparison to other forms of pipe. This aspect is discussed in detail in Sections V and VI.

III

USE OF PLASTIC PIPE

Historical Development

The economical and efficient transportation of water for personal and household needs from distant sources to convenient use points has been a continuing challenge to the ingenuity of man since he first started to live in communities. The open trench was followed by the hollowed log, masonry channels, pierced stones cemented together, tunnels and aqueducts. Ancient pipes made of baked clay have been found in such widely scattered places as Mesopotamia and Tula, seat of the empire of Quetzalcoatl in Mexico. The Nabatoeans of Petra in Transjordan used clay pipe probably about the second century B. C. Their Roman contemporaries were using lead pipe.

A major break-through in development of a satisfactory pressure water pipe occured about 1664 when King Louis XIV of France ordered the construction of a cast iron main extending 15 miles from a pumping station at Marly-on-Seine to Versailles to supply water for the town and the fountains. The bell and spigot joint, invented in England in 1785, soon replaced the original flanged joint with lead gaskets and has been extensively used ever since.

Asbestos cement pipe, developed in Europe prior to World War I, was introduced into the United States in 1929 and has steadily encroached on the field once nearly dominated by cast iron pipe particularly in the diameters from 4 inches to 24 inches.

About the same time, another newcomer–plastics–entered the field with far-reaching results that have astonished even the developers of the material. Whereas some of the other materials used for piping have had one or two superlative characteristics to recommend them, plastics combine a good combination of properties rather than extremes of any single property (except extreme resistance to corrosion). It is the only material that may be simultaneously strong, light, flexible and comparatively inexpensive.

One of the first commercial plastics was cellulose nitrate, popularly known as celluloide, developed in 1860 as an ivory substitute. Cellulose acetate was developed in 1890 and bakelite–a thermosetting polymer–was produced in 1905. These were the forerunners of the plastics commonly used at the present time for production of pipe—namely, polyvinyl chloride (PVC); polyethylene (PE); acrylonitrile butadiene styrene (ABS); styrene-rubber (SR) and polybutylene (PB).

1931 PVC compounds were developed by German scientists who proceeded to produce millions of pounds, some of it for pipes. PE plastic was developed on an experimental basis in Great Britain in 1940 and was being extruded into pipe by 1948. The first production of thermoplastic pipe in the United States was in 1941. In 1948 the output was valued at $500,000. In 1957, output of thermoplastic pipe and fittings was 62,400,000 pounds valued at approximately $50,000,000 The more than 300,000,000 pounds produced in 1967 consisted of 0.9 to 1 billion feet of pipe valued at $187,000,000. Water supply and distribution systems are the largest users of plastic pipe (36 percent). Other major uses include gas distribution, sewer and drainage systems, electrical conduit, chemical processing industries, and drain, waste, and vent plumbing. (See Figure 4.)

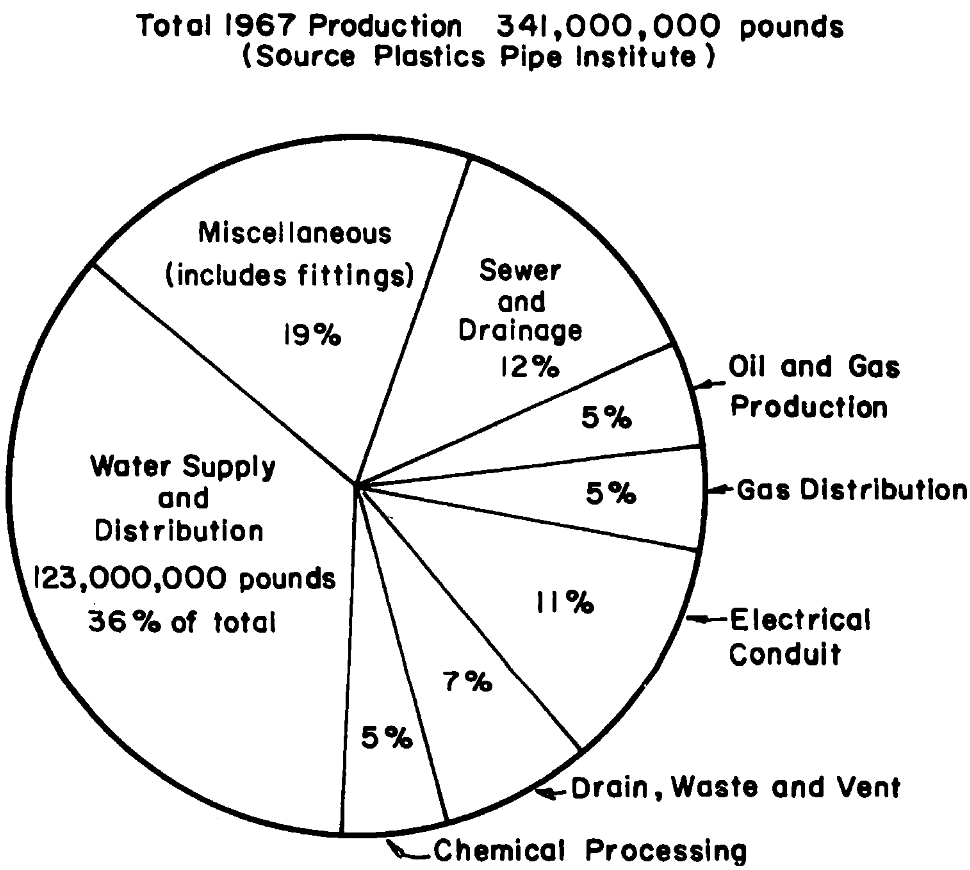

Figure 4

1967 U.S. PLASTICS PIPE PRODUCTION BY END USE

Conservative estimates predict an annual production in the U. S. valued at $350,000,000 by 1972 doubling the 1967 production within 5 years.*

Behind this picture of accelerated growth of the use of plastic pipe are such factors as continuing standardization programs; more and more code approvals; advanced manufacturing techniques and improved joining materials; advent of new materials with greater impact strength and higher temperature resistance; continuing and increasing understanding and acceptance by designers, contractors and purchasing agents of the different kinds of plastics pipe available, how they may be specified and how they should be used.

There have been some failures in the use of plastic pipe–some caused by poor materials, others by the use of materials under conditions beyond their design capabilities, others by improper installation. Unfortunately, failure of new products seems to be well-remembered, whereas successful usage is often ignored. However, with more experience in the use of plastic pipe and a better understanding of the varied characteristics of the different types of plastics, an "improved image" is emerging. New markets are opening up and it is quite likely that the predicted 1972 market of $350 million will be exceeded.

Increasingly the frontrunner in the plastics piping field is polyvinyl chloride (PVC) which, on a poundage basis began outstripping polyethylene (PE) in 1964-1965 and has continued to increase. Skyrocketing in volume from 16.5 million pounds in 1962 to 112 million in 1967, PVC pipe has averaged an annual growth rate of 47 percent for the six-year period compared to PE's 9 percent.

A breakdown of the 1967 total of 318.5 million pounds** by resin type shows PVC in the lead with 112 million pounds followed by PE with 75 million pounds, SR with 45 million pounds, and ABS with 37 million pounds. Fittings accounted for 40 million pounds and 9 million pounds of other miscellaneous types of plastic pipe were produced for the total of 318.5 million pounds**. (See Figure 5.)

PVC's range of useful properties is felt by many to make it the most versatile of all the plastics used in pipe, a fact attested to by the variety of applications and number of markets served by pipe made of this material.

The big growth market for PVC is water supply, particularly water mains and other large-diameter water pipe. Another promising outlet for PVC is drain, waste and vent (DWV) installation which some observers believe may in the future tend to favor PVC rather than ABS, now widely used for this purpose.

Table 5 is a summary comparison of the material, properties, application, allowable maximum use, temperature, and standards for the several types of plastics of most interest in the water supply and sewerage fields. The many other uses for plastic type are also outlined.

*Production estimates are by the Plastics Pipe Institute. Plastic pipe will be issued a separate Standard Industrial Code (SIC) classification by the Department of Commerce beginning January 1, 1970.

**Excluding electrical conduit.

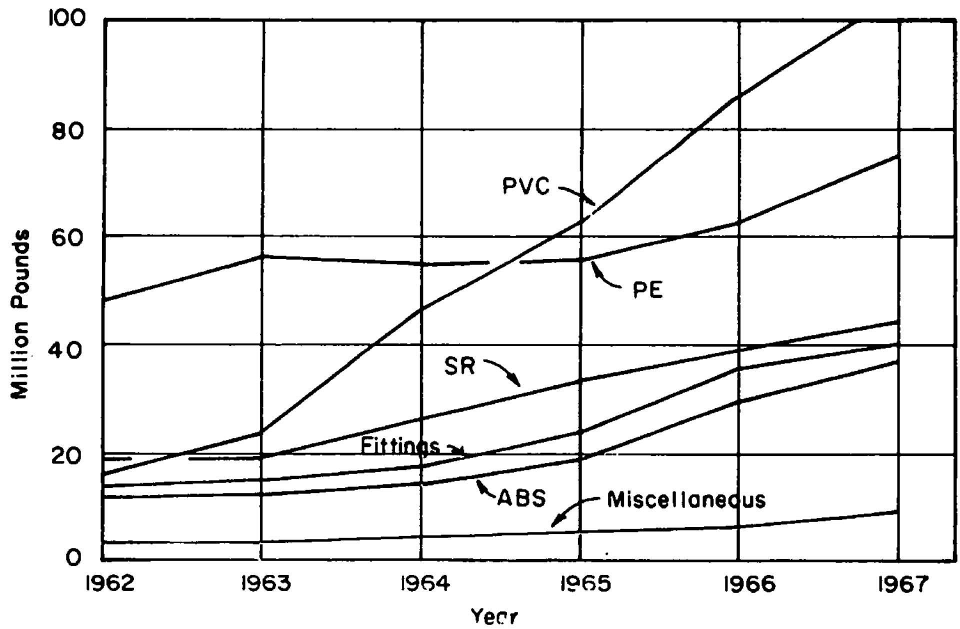

Figure 5

PLASTICS PIPE PRODUCTION BY MAJOR CATEGORIES

Identification

Plastics pipe materials are designated in the United States by an abbreviation indicating the type of material used (ABS, PE, PVC, et al)* followed by a four number code. The first numeral designates the type, the second the grade, and the last two numerals the recommended design stress to the nearest 100 psi at 73°F. Types and grades do not refer to quality but to classification systems given in ASTM standards and are based on properties. ABS 1316 is Type 1, grade 3 with a recommended design stress of 1600 psi. ABS Type 1 grade 3 is the strongest of the ABS compounds.

PE 3306 is Type 3, grade 3 with a recommended design stress of 630 psi. This is a high molecular weight pipe material. There is also a higher molecular weight polyethylene material with the same designation which has a greater ability to withstand repeated applications of stress. The designation of these materials is being changed to PE 3406. Three of the compounds have design stresses of 630 psi: PE 2306, 3306, and PE 3406, and are the most used by water utilities.

PVC 1120 is type 1, grade 1 having a recommended design stress of 2000 psi. PVC type 1, grade 1 and PVC type 1, grade 2 have design stress values higher than other PVC compounds.

*PVC, PE, and ABS, in that order, are the major plastics material used for pressure pipe for potable water service.

As a basis of specification development, the user may refer to manufacturer's specifications, to the plastics industry voluntary commercial standards published by the U.S. Department of Commerce, the Standards of The National Sanitation Foundation (see Appendix G), and the standards and specifications of the American Society for Testing and Materials. A complete list of relevant published specifications appears in Appendix C, "Standards and Specifications for Plastic Pipe." Appendix H, "Installation of Plastic Pipe," may also be useful.

Acrylonitrile-Butadiene-Stryene (ABS)

ABS pipe is a tough material which offers excellent impact-resistance, even at low temperatures. It has good dimensional stability and is one of the higher heat-resistant plastics with an upper temperature limitation of 160°F, depending on the compound. There is one being used at 180°F. The hydrostatic design stresses (the estimated maximum stress in the wall of the pipe in the circumferential orientation due to internal hydrostatic pressure that can be applied continuously with a high degree of certainty that failure of the pipe will not occur)* for water at 73°F are 1000, 1250, and 1600 psi. ABS pipe is produced under Product Standards PS18-69 and PS19-69. Materials are referenced in ASTM D2282-67 to three ABS plastics. It has excellent corrosion and chemical resistance to non-oxidizing chemicals. It can be joined by solvent cementing, or when wall thicknesses are adequate, it can be threaded with standard pipe threads. Heat forming of this material to make bends in the field is not considered good practice.**

ABS pipe began moving toward large scale production in 1965 shortly after it and PVC were accepted by the Building Officials Conference of America (BOCA) for drain, waste and vent pipe (DWV). It is particularly useful for this type of application where the so-called DWV "trees" can be factory built and delivered to the job to be put in place before kitchen and bathroom fittings are installed. The pipe tree with all connections preassembled is carried to the point of installation by one man instead of the two or three required for a similar tree made of metal pipe. In 1966 it was estimated that 1 in 10 of the new houses built used ABS pipe for their DWV installations and virtually all of the 200,000 mobile homes produced that year were so equipped.

ABS has some disadvantages. It is available only in relatively short lengths - normally 20 feet. It is subject to attack by some organic solvents and is not as flexible as PE pipe. It is affected by sunlight on long-term exposure with its impact strength and elongation properties being materially decreased on direct exposure. Carbon black is usually added to the ABS compounds to minimize the effects of ultraviolet exposure and to color it.

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*See Appendix D, "A Glossary of Plastic Piping Terms," for definitions.

**See Appendix H, "Installation of Plastic Pipe," for further information.

Polyethylene (PE)

PE plastics vary from soft to rather hard products extremely resistant to chemicals. They are so resistant that they cannot be joined by solvent cementing to produce strong bonds. PE pipe is usually joined by flaring, insert fittings, or heat fusion.

PE pipe is normally produced under the requirements of Product Standards PS 10-69 and PS 11-69. Materials are referenced in ASTM 2239-67 to three types of PE plastics all of which are considered flexible but the higher the density the more rigid the pipe; in fact, tensile strength, surface hardness, softening temperature and chemical resistance all increase with density and molecular weight. PE pipe may be manufactured from any of the three types of raw materials available and in design stresses (normally 80 psi, 100 psi, 125 psi, and 160 psi) and Schedule 40 dimensions. PE pipe produced from any of the resin types according to the Commercial Standards* will perform on a comparative basis from a working pressure standpoint. The only variation will be the flexibility of the pipe.

Confusion may result when American and European polyethylenes are compared. In Europe they are classified into two groups, high and low density whereas in the United States there were three groups sometimes called low, medium and high, and more recently a breakdown of "high" into two, giving four.

Among the decided advantages of PE pipe are its low cost, its light weight which makes it easy to handle, and its flexibility which makes it possible in the lower densities to coil it into extremely long lengths from 100 to 2000 feet. It is produced in sizes from 1/2-inch to 6-inch with perhaps the greatest volume in the Type II or medium density material. The pipe is available in copper tubing sizes which can be flared with the application of a moderate amount of heat and connected to water works fittings using the standard copper flare nut. It is also made in iron pipe I.D. and O.D. sizes which can be connected to water works fittings using special adapter flare nuts, bronze insert fittings or compression type fittings.**

The disadvantages of PE pipe are its low hydrostatic design stress and relatively poor rigidity. The temperature limitation varies from 100 to 180°F, depending on density. Polyethylene pipe is sensitive to light, although it may be left in the open a month or more. This is offset by the addition of carbon black in the amount of 2 to 2.5 percent during compounding. It is flammable and burns steadily although the flame can be easily extinguished.

Polyvinyl Chloride (PVC)

PVC pipe is rigid and has operating temperature limitations of about 150°F. It has good dimensional stability and excellent weathering characteristics. Unlike ABS and PE which are usually produced as black pipe, PVC is produced in many colors. It is extremely resistant to chemicals such as

*Now known as Product Standards (see Appendix C).

**See Appendix H, "Installation of Plastic Pipe," for further information.

oils and has excellent mechanical strength and rigidity. PVC is self extinguishing.

It may be obtained with plain or a bell end. Also it may be joined by heat fusion or solvent cementing, mechanical joints of various design, and can be readily threaded if the wall thickness permits. (Schedule 80).* It is produced in sizes ½-inch through 12-inch with some pipe being produced up to 16-inch diameter. It is furnished in lengths of 20 to 40 feet. Some Type II's can be coiled. It is available in a complete range of iron pipe and copper tube diameters together with valves and fittings.

PVC pipe is generally extruded against Product Standards or those published by the American Society for Testing and Materials (ASTM). (See Appendix C.) Extrusion of PVC pipe (as with ABS and PE pipe) in accordance with these standards assures that the working pressures for a given schedule or pressure rating are comparable. ASTM D2241-67 covers four PVC plastics. Type I PVC is a material with high resistance to chemicals and the Type II compound has high impact characteristics. The Type IV PVC compound which is a polyvinyl-dichloride (CPVC) has high temperature resistance. PVC pipe is produced to perform over a wide range of working pressures.

As with the other types of plastic pipe, there are a few disadvantages: the fact that it is readily softened by ether, ketones, and chlorinated hydrocarbons, and, compared to PE and ABS, it is a heavier material.

Because of the many advantages of PVC pipe, it is outstripping all the other plastics on a poundage basis. On a footage basis PE still leads because its lower specific gravity results in the production of more pipe per pound of resin than with PVC.

Other Plastics

While not in wide scale production, numerous other plastic materials are used in fittings or in special piping applications. Some of these materials such as the polybutylene, polypropylene and others have higher tensile strength and higher temperature characteristics. Polypropylene is reported to withstand temperatures up to 300°F without loss of physical properties.

Plastic resins and compounds are constantly being improved and new ones will be produced which will permit the expansion and broadening of the use of plastics in the potable water and sewage disposal fields. Such improvements will make plastic pipe more economical in both pressure and non-pressure systems.

Reinforced Plastic Pipe

One of the most important developments in plastic piping in the chemical industry has been an increasing trend toward the use of large diameter plastic pipe. A number of companies, responding to the demand, are actively engaged in the production of such pipe. One major fabricator, for instance,

*See Appendix H, "Installation of Plastic Pipe," for further information.

has recently installed several miles of 48 to 54-inch diameter glass-fiber-reinforced polyester (FRP) pipe on the ocean floor for the waste disposal of paper mill effluents. Another company announced recently that it had manufactured 6000 ft. of 42-inch diameter FRP pipe as a service line to handle highly corrosive chlorine, chlorine dioxide and hypochlorite. Similarly, a third company is manufacturing glass filament-wound reinforced pipe up to diameters of 12 feet and in sections up to 60 feet long.

The industry at large appears to be quite interested in the application of such large diameter pipe. The M. L. Sheldon Corp. recently used lightweight flexible 12-inch polyethylene pipe for handling a pulp mill effluent crossing the harbor between Watson Island and Rodney Island in Prince Rupert, British Columbia. They reported that the 12-inch pipe was first fused together by field crews into continuous sections, one of 165 feet and three of 800 feet, with flanged fittings on either end. Concrete collars each weighing 450 pounds were fixed at 10 feet intervals to adjust the buoyancy of the pipe, which weighs 6 lb/ft., so it would sink when filled with liquor.

The sections were assembled at dockside in preparation for floating across the harbor. Then, the 2,560-ft. line was towed across the harbor by a small boat, the entire operation requiring only one day in spite of the strong winds and tides. At dockside the line was fixed to the stainless-steel pipe from the pulp mill. Finally, the pipe was simple filled with seawater to sink it to the bottom and allow it to follow the contours of the harbor bed; and the effluent red liquor from the pulp mill displaced the seawater as it left the plant.

Recently, United Technology Center, Division of United Aircraft Corp., announced development of a composite-structure sewer pipe, called Techite. This pipe, fabricated of polyester resin and sand mortar reinforced with continuous fiber-glass filaments, withstands severe earth loads resulting from high earth cover or unstable soil conditions. It is manufactured in 10-ft. lengths, in diameters of 8 to 41 inches. Larger diameters can be custom fabricated. Present use is largely in non-pressure installations.

A number of other companies currently manufacure a similar type of polyester or epoxy sand-mortar glass fiber composite in very large diameter pipes.

Probably one of the most unique piping innovations for corrosion-resistant applications was the introduction by American Cyanamid Corp. of a coiled, uncured, polyester pipe, called Cychem, which can be field-inflated and steam-cured in 500-ft. lengths. This pipe is constructed of four distinct layers: an internal chemical-resistant barrier of synthetic-fiber-reinforced hydrogenated bisphenol-A polyester resin, a layer of highly impermeable-plastic film, a multiple continuous filament winding that provides high burst strength, and an external layer similar to the internal layer. The piping is able to follow any ground contours, be stretched between various levels through congested piping or sewers, thus eliminating the time and expense of excavation, and then cured to a rigid pipe by steam in one hour. It is available in 2 to 6 inch diameters and operating pressures to 150 psi.

Another ingenious use of plastic for the manufacture of pipe is the "Truss Pipe" which derives its name from its cross-sectional configuration with the concentric inner and outer wall of ABS plastic connected in trusslike fashion by webs of the same material with intervening spaces filled by lightweight concrete. The ABS walls carry tensile and compressive stresses while the concrete helps to maintain the truss shape, and carry the compressive stresses as well as provide local support against impact load. This pipe, developed for sewer use, is lightweight and exhibits a practical balance of stiffness and flexibility. It has tight but simple solvent cemented joints, the ability to be tapped, low-resistance to flow and high resistance to grease and slime accumulation. Joints are made with a sleeve-type coupling attached to one end of each pipe section. The insides of the coupling and the plain end of the next piece of pipe are coated with a primer and then with a cement consisting of ABS in methylethyl- ketone after which the plain end is stabbed into the coupling.

The American Society of Testing Materials has issued a standard, ASTM D-2680-67T, for this type of material. The pipe, available in 8, 10, 12, and 15-inch diameters, has been approved for FHA-insured construction.

Trend to Larger Pipe

Perhaps the most significant recent development is the introduction of the larger diameters in the pressure pipe range. As a result of research, and new tooling design, pipes of 12, 14, 16, and 18-inch diameters have been commercially produced, not only for water use, but also for use for sewage and effluent pumping mains including marine outfalls. Pipe up to 72 inches in diameter is forecast within several years.

IV

PLASTIC PIPE STANDARDS AND CODES

Introduction

Standards are of mutual advantage to all users. Purchasers benefit because:

(1) Standards assist the purchaser in evaluating differences that exist in materials in which he has no particular competence or experience.

(2) Purchasers can select from a number of suppliers all of whom have met the same minimum requirements.

(3) Standards reduce cost as well as raise quality through the elimination of special designs.

(4) Purchases by reference to standards by number and title save time, money and effort, and reduce chance of error.

Producers benefit because:

(1) They can produce to a standard at less cost and deliver a superior product. They are prerequisites for the mass-production assembly line.

(2) Without standards producers would be called upon to meet an unlimited number of special requirements. They create stability and regularize techniques of measurement.

(3) Adherence to standards in purchasing protects ethical manufacturers from unscrupulous competition.

The public benefits from the assurance that purchases made under the approved standards will result in satisfactory performance at reasonable, competitive prices.

Pipe and material specifications and dimensions in the United States are largely the province of the American Society for Testing and Materials

(ASTM), American Water Works Association (AWWA), U.S. Department of Commerce Product Standards (PS), National Sanitation Foundation (NSF), and the American National Standards Institute (ANSI). A complete list of U. S. standards and specifications for plastic piping and components appears in Appendix C. Many foreign specifications are also listed.

Distribution Design Needs

The major stress encountered in water distribution service is that caused by internal water pressure. The challenge that faced the plastics industry was to develop test and evaluation methods to obtain useful and proper information for the design and rating of plastic pipe so that it could cope with these stresses for suitably long lengths of time. An entirely new method had to be developed.

First, the various plastic pipe materials had to be defined; ASTM specifications served this purpose. The "Hydrostatic Design Stress Test Method" itself was developed jointly by the ASTM and the Plastics Pipe Institute* as was a refined raw-material designation to classify the materials in terms of pressure pipe use.

This method uses long-term burst test data, requiring testing for a period of more than a year, which is used to provide a reliable and statistically significant basis for extrapolation. A hydrostatic design strength is then obtained and it together with the service factor provides a hydrostatic design stress for safe operation over a long period of time.

From this information and the use of ANSI preferred numbers series, pipe wall thicknesses can be determined for each evaluated material to give established pipe pressure ratings.

There are today 200 separate types and grades of plastics compounds of more than 100 trade name materials, with more than 20,000 stress-rupture points that have been analyzed by this method, and the quantity of data studied is continually increasing.

Standards

The primary result of this work has been the establishment of plastic pipe component standards for standard dimension ratio pressure-rated plastic pipe. These standards form a sound basis for end use standards.

The adoption of these commercial standards and the resulting simplification of some series to iron pipe size outside diameters means that the use of plastic pipe can be tied into existing pipe systems and practices, including the use of compression, threaded, or flanged fittings for transition from other materials with no change in accepted practices and stocking programs.

Additional work on standards now underway includes impact and crush test methods, revision of all schedule size standards to include performance requirements, industry approved revisions of fitting standards, and a cycling pressure test method. There are over 50 individual standards projects under

*See Appendix B for references.

way, many of major magnitude. AWWA and ASTM committees are preparing installation specifications.

The promulgation in Great Britain and Germany of standards for plastic pipe, though not having the rigid quality requirements of the Product Standards, has resulted in skyrocketing use of plastic pipe in the water supply field. In Japan about 60 per cent of the small-diameter pipe used today is plastic. Similar acceptance of plastic pipe in the United States, with its large population and large geographic area, can be expected.

National Sanitation Foundation Participation

The Pipe Division of the Society of the Plastics Industry initiated in 1951 a testing program with the National Sanitation Foundation (NSF) at the University of Michigan. The resulting report, "A Study of Plastic Pipe for Potable Water Supplies," was issued in 1955. At that time, Dr. Henry Vaughn, Dean of the School of Public Health stated:

> "In these days of rapid development of untried new materials, health officials naturally are concerned about the possible effects of adding such materials to our environment. . . . .This impartial study of plastic pipe from a public health point of view is an attempt to secure, for public health officials, much needed basic information.

The NSF program has grown from the original toxicity tests to include vitally important performance specifications, and NSF now has the most complete physical testing facilities for large-scale continuing testing programs on plastic pipe in the United States. Under the contract between NSF and participating firms, allowing the use of the NSF seal, strict conformance by plastic pipe manufacturers to Product Standard and ASTM specification is insured by strict enforcement procedures. The importance of the Product Standards and ASTM Standards and the NSF seal on all plastic in all U.S. water systems installations can not be overstressed. The NSF seal is public health equivalent in the field of the Underwiter's Laboratory label for electrical equipment. Probably over 90 percent of plastic pipe installed in public water systems bears the NSF Seal of Approval.

The cost of such a program of testing may be estimated from recent correspondence with the National Sanitation Foundation:

(1) "The annual Listing and service charge for a pipe manufacturer is \$350. In addition, testing charges are (a) complete toxicological - \$325 and (b) performance evaluation of each material classification of pipe - \$275. Costs are periodically adjusted.

(2) No specific percentage of a manufacturer's output is tested. Rather, random samples are tested at least annually. Frequency of plant visits varies dependent upon problems encountered, quality control procedures and volume.

(3) We have no knowledge as to the percentage or proportion of plastic pipe in the United States which is produced under the NSF program. We have been advised, however, that 90 to 95% of all plastic pipe manufacturers are participants.

(4) We do no testing overseas; however; we do have plastic companies in Europe who are participants in the program insofar as those products that they manufacture for import into the United States are concerned. Special conditions may be considered, however.

(5) We are in a position to extend our services to those foreign firms who import to the United States. The testing and listing charges are identical. The only additional cost being that for transportation and expenses. We have not seen fit at this point to franchise overseas laboratories. Although this may be considered when volume reaches a point which deems it feasible."

In 1965 the NSF published its Standard No. 14 for Thermoplastic Materials, Pipe, Fittings, Traps and Joining Materials. Its purpose is "to establish the necessary public health and safety requirements for thermoplastic materials, pipe, fittings, valves, traps and joining materials based on specific end use and application, and to provide for conditions and provision of evaluation thereof." It is reproduced in part as Appendix G.

As mentioned above plastic pipe and fitting standards have been or are being developed by many countries. The International Standards Organization has developed several recommendations including R330, Pipes for Plastic Materials for the Transport of Fluids (Outside Diameter and Normal Pressures.) This recommendation carries the following statement on the cover sheet. . ."For each individual country the only valid standard is the national standard of that country."

Japan has its Japanese Industrial Standards including one for Rigid Polyvinyl Chloride Pipes for Water Works - JIS K 6742-1965. Israel's standards include one for Hard Polyvinyl Chloride Pipes for carrying Drinking Water, S.I.532. The British Standards Institution has a number of standards or specifications for plastic pipe including one for unplasticized PVC Pipe (Type 1140) for Cold Water Supply. The Instituto Nacional de Normas Tecnicos y Comerciales (INANTIC) of Peru has issued standards for PVC Pipe for the Conduction of Fluid Under Pressure, No. 399-002 and PVC Pipe for Wastewater. In Mexico the Institute for Engineering will issue "Quality Standard and Methods of Testing PVC Pipe" in January 1969. Other foreign specifications are listed in Appendix C.

Specifications

Specifications and standards are required to insure that the purchaser obtains the quality of material having the correct dimensions which he requires. A specification for plastic pipe for a potable water use would include the following: (1) that the pipe be manufactured from PVC, PE, ABS or some other known material with the characteristics that the user has selected, (2) the required pressure rating, (3) for each kind of material, the specific designation, e.g., PVC 1120, must be specified, (4) quality of material, (5) workmanship, (6) approval for potable water, (7) pipe dimensions and tolerances, (8) pipe requirement such as minimum bursting pressure and sustained pressure, test requirements, packaging, (9) qualification for manufacturing and rejection. It is important to note the wording of the Product Standards and the ASTM specifications: "All pipe intended for use with potable water shall meet the specifications of the National Sanitation Foundation Testing Laboratories, Inc., or other accredited laboratories recognized by Public Health Officials." (This is applicable in the United States and may be paralleled by similar requirements in other countries.)

Some users require that the manufacturer be able to demonstrate successful use of his pipe in water service for a number of years. This may assure the user that the manufacturer's past record is satisfactory, but it becomes somewhat restrictive upon manufacturers who are new in the business. There is no substitute for an actual inspection of the manufacturer's plant and a check upon his in-plant quality controls. Some manufacturers furnish a full guarantee on their material.

Testing

In the United States in 1955 when the National Sanitation Foundation (NSF) Research Study on Plastics was completed and it was determined that pipe made from virgin thermoplastic resins and compounds would not produce deleterious effect to drinking water, the number of manufacturers who offered plastic pipe for potable water uses began to increase. It was soon recognized by the plastics industry and by health and water works officials that there was a need for a testing and identification program of plastic pipe on a continuing basis. The plastics industry asked the National Sanitation Foundation to establish a continuing testing and certification program to assure the suitability of plastic pipe for drinking water purposes. Certain unscrupulous manufacturers were using scrap plastic and reclaimed materials from unknown sources for the production of plastic pipe which was being offered for potable water service with no assurance of its meeting the requirements of that service.

The NSF brought together a Public Health Advisory Committee to meet with the plastics industry leaders to outline a program for continuous testing and certification of plastic pipe for cold water service. It was agreed by this Committee that the Product Standards of the U.S. Department of Commerce should be used as a basis for physical testing. The Product Standards reference acceptable ASTM test procedures which are used by the NSF Testing Laboratory. The performance specifications of the Product Standards and ASTM specifications are based insofar as possible on a 50-year life and include, as required by the applicable standard, test requirements for sustained pressure (1,000 hours), quick burst, impact resistance, dimensions and tolerances, and other quality control requirements. Plastic pipe is subjected to the tests shown in Table 6 during manufacture.

TABLE 6

TESTS ON PLASTIC PIPE DURING MANUFACTURE

Test	ABS	PE	PVC	ASTM Designation
Carbon black		x		D 1603
Ballooning	x	x	x	D 1598
Burst pressure	x	x	x	D 1599
Density		x		PE Specifications
Eccentricity	x	x	x	D 2122
Environmental stress cracking		x		PE Specifications
Extrusion quality	x		x	D 1939/D 2152
Failure	x	x	x	D 1598
Flattening			x	D 2241
Inside diameter measure		x		D 2122
Outside diameter measure	x		x	D 2122
Seepage or weeping	x	x	x	D 1598
Sustained pressure	x	x	x	D 1598
Wall thickness	x	x	x	D 2122

All tests are conducted under rigid controls at the standard test temperature of 23° C (73.4° F). Sustained pressure test for PE is also conducted at 100° F. For recommended test frequencies, see appendix A-4, ASTM D 2513.

These tests are added to those related to the toxicological and organoleptic aspects of the pipe involving tests of toxicity, taste and odor and the resistance of plastic pipe to use conditions.

Before any plastics pipe compounds, proposed for use in pressure piping applications, can be accepted by the NSF, it is necessary that the manufacturer of the compound develop design stress data and furnish evidence that the design stress has been developed in conformance with the tentative Method for Estimating Long-Term Strength and Working Stress of Thermoplastic Pipe prepared by the Plastics Pipe Institute. The above data are developed according to the standard procedure over a period of 10,000 hours testing. The data may then be used to project the 100,000 hour design stress of the material.

The NSF makes first-hand inspection of plastic production and collects samples of pipe from the extruders, from storage, from warehouses and from points of installation for control testing. The sampling of plastics materials and pipe is carried out on a surprise visit basis. These unscheduled visits are made of plants where the NSF Seal is being placed on plastic pipe. State and local health department engineers are also helpful in collecting and submitting samples of pipe from points of installation.

The NSF insignia on plastic pipe of all types manufactured under the present Seal of Approval Program signifies that the pipe is safe for potable water uses and that it conforms with the physical specifications of the applicable Commercial Standard for the material concerned. In those instances where there is no standard, the pipe is tested against the hoop stresses recommended and proven by the material manufacturers and using the ISO* formula to determine the test pressure.

In early 1964 a survey by NSF indicated that better than 90% of the population of the United States were served by health agencies utilizing or requiring the NSF insignia on plastic pipe as being evidence of the pipe's suitability for potable water uses. Numerous governmental agencies, municipalities, water districts and similar jurisdictions utilize the NSF Seal as a means of assuring themselves of the public health safety and performance capabilities of plastic pipe.

The testing laboratory facilities of NSF are being used by some foreign manufacturers of thermoplastic pipe to earn the right to distribute their product in the United States with the NSF Seal affixed. NSF has expressed a willingness to assist other countries to develop programs for testing and certification of plastic pipes manufactured in those countries. Some preliminary discussions are actually underway in Latin America. A formal quality control program is necessary to assure the physical, toxicological and organoleptic qualities of the plastic pipe used in potable water supply systems.

Determination Of Wall Thicknesses

When equations relating design stress to pressure rating are used or schedule size pipe is pressure rated, the rating decreases as the pipe size increases because the diameter-to-wall thickness ratio increases as the pipe size increases. Thus a piping system must be designed for the largest size pipe and is overdesigned for the smaller sizes. To correct this engineering problem, the plastic pipe industry devised a series of wall thicknesses such that the diameter-to-wall thickness ratios (Standard Dimension Ratio, SDR) are constant, resulting in the same pressure rating for all pipe sizes in any one series. This resulted in the addition of pressure rating tables for water at 73°F to the ASTM and Commercial Standards. From these tables, for example, in SDR21 pipe for PVC 1120 plastic material, the pressure rating is 200 psi for water 73°F regardless of the size of the pipe. For Schedule 40 pipe (which is not SDR) the pressure ratings for PVC 1120 plastic material for water at 73°F are 220 psi for 4-inch and 450 for 1-inch pipe.

Joints and Fittings

Much harm has resulted from the belief that the installation of plastic pipe is a do-it-yourself job. This leads workmen and some engineers to believe that anyone can do a good job, regardless of the way he does it. Nothing can be farther from the truth as evidenced by some of the early failures of plastic pipe installations. Like any other piping, a satisfactory installation is obtained

*International Organization for Standardization. See Appendix H, Par. 3.14, Pressure Rating, for further information.

only when the system is designed properly and the specified components are used. Workmen must be trained, both by instruction and field experience, so that they know how to make a proper installation. Good workmanship is the final step in achieving a satisfactory piping system.

Fundamental to the proper installation is a realization that the type of joint used with plastic piping and fittings depends on the type of materials involved and on the particular application. Detailed information on joints and joining appears in Appendix H. A few highlights follow.

PVC material may be joined by any of several different methods. PVC pipe may be obtained with plain or bell end and may be jointed by fusion or solvent cementing or may be readily threaded if the wall thickness permits.

For solvent cementing, the solvent should be that specified by the pipe manufacturer and care must be taken to prevent use of excessive amounts of solvent. Such excessive amounts result in buildup of material inside the joint and may cause a weakening of the sidewall. Insufficient solvent may result in a weak and leaking joint. Proper curing time, approximately 24 to 48 hours, must be allowed before pressure can be applied. The joints should be left uncovered for observation and testing. Solvent cemented joints must be free of moisture, oil, or other foreign material. Temperature has a definite effect on the time it takes for a solvent joint to attain its full strength.

The following conclusions were drawn by the Water Research Association of England from strength tests on 3/4 inch and 1 inch spigot and socket joints on PVC pipe:

(1) Differences in strength due to the different cements (four were used) are probably too small to be of practical importance. Careful preparation of the mating surfaces, together with use of an adequate amount of cement are more important than choice of cement.

(2) Strength of taper socket joints is superior to that of parallel socket joints.

(3) For maximum joint strength, parallel socket joint clearances should be less than one or two thousandths of an inch and the taper socket joints should be less than one degree.

(4) The lengths of commercially available parallel sockets are adequate to give satisfactory joint strengths provided the clearance is kept small and the joints are made in a workmanlike manner.

*(5) Joints reach approximately half their ultimate stength after four hours, but they are still not fully matured after one week.

If heat forming is used, care must be taken. Unevenly heated areas and areas heated beyond the point of softening may be permanently damaged.

*"Necessary cure time can vary from minutes to days depending on conditions and the solvent cement used. . ." ASTM D2855-70

This pipe can be crimped-off in the thinner-wall small diameters, but the crimped area must be straightened and reinforced, usually with a solvent cemented collar.

In heavy-wall pipe such as Schedule 80 of Class T, threaded fittings may be used in iron pipe size. Teflon pipe tape may be applied to help assure a watertight connection.

When bell ended pipe is used, a multi-ribbed rubber ring provides the seal and makes a flexible joint installation. This can be compared to the conventional bell and spigot rubber ring push-on joint. This type of connection offers a further advantage of permitting the line to be filled, tested and placed in service without waiting for solvent cemented joints to set.

PE pipe cannot be connected by solvent cementing or by the use of threaded fittings. Plastic or metal insert fittings using high-quality stainless steel clamps or compression-flared connections may be used. Insert fittings place a restriction in the line which increases the head loss - consequently delivering a smaller quantity of water. Where low pressures obtain in the water system or high delivery of water is required, insert fittings are not recommended.

A moderate amount of heat is required for flaring operation. Heating should be carefully controlled to avoid uneven heating or over-heating. Heating beyond the point of softening, when making flares, may result in changes of dimensions and may cause permanent damage, although PE material does not appear to be as adversely affected by heat as PVC or ABS.

On sizes 1½-inch in diameter or larger where insert fittings are used, consideration may be given to the use of double clamps. Clamps should be of high quality stainless steel. Clamps made of inferior material may result in early failure of the clamp. Material should be allowed to cool before the coupling is tightened and the material stressed.

This PE material may be crimped off with no damage to the pipe and no straightening or reinforcing required. Reasonable care should be used in handling and installing. PE material is more resistant to impact than either PVC or ABS but is more easily cut by sharp objects.

Fittings for the pipe should be constructed of the same material used for the pipe except for insert fittings. Fittings should be of the molded type injected from molding compound.*

Installation**

Effective specifications on the installation of plastic pipe are as important as adequate material specifications. The importance of proper installation procedures for pipes of other materials has long been recognized. Plastic pipe is no exception--it is just slightly different in its requirements.

For all plastic pipe materials usually used for potable water installation, care is required in bedding and backfilling practices. Reasonable care should

*For further information on jointing, see Appendix H.

**A complete guide and outline specification for installation are given in Appendix H.

be used in handling and installing. PVC pipe must be stored away from heat and sunlight. If exposed to direct sunlight, bowing is likely to occur because of the temperature differential between the top and the bottom of the pipe. In the case of bell-ended pipe, the bell is apt to deform. ABS and PVC can be damaged by the impact of hard, sharp backfill material. PE has more resistance to such impact but is more easily cut by sharp edges. There is also the possibility of imposing secondary stresses that may cause failure sometime far in the future. In any event trench preparation and backfilling specifications should be somewhat similar to those used for asbestos cement pipe, namely that fine granular material should be used until the pipe is well covered.

Another problem is that when PE tubing is unrolled it tends to coil.* When bent for installation as when making the bend from the trench up to the angle stop or curb stop it tends to straighten out. A means must be employed to keep the bend in place until the final connection is made and backfill is placed. Backfill, alone however does not ensure that the tubing will stay in place. It is recommended that the tubing be tied with twine or rope across the bend or be tied to a stake. Heat should never be used in making a bend because the tubing may be weakened and early failure may occur.

In the case of non-end-load-bearing joints pipelines must be anchored at changes of direction, also at valves and tees, etc. The size of the thrust block will depend on the bearing capacity of the soil and should be assessed as for pipes of other materials. When placing concrete on a plastic pipeline care should be taken to avoid encasing the pipe completely. This is because of the slight flexibility of plastic pipe when it is in concrete or when it is clear of the concrete may cause a tendency for it to shear at the interface between concrete anchor and the backfill, unless the pipe is properly supported. A thin membrane such as kraft paper, plastic sheet, or unbituminized roofing felt should be used between the concrete and the plastic pipe.

Pipes may be joined at the side of the trench and then placed in the trench by lowering with ropes. Pipes should never be dropped into the trench. Care must be taken during this operation to avoid excess strain on pipes or joints. Solvent cemented pipelines should not be snaked into the trench until the joints develop sufficient strength (see Appendix H for details). If rubber ring joints are used they should be checked after the pipe is fully positioned in the trench to ensure that they are still fully engaged. When laying pipe in a trench, a small amount of slack should be provided to allow for temperature contraction. The final connection should not be made until the pipe is at ground temperature.

One advantage of using plastic pipe, which can be joined at the edge of the trench and lowered into place, is that width of the trench may thereby be reduced. For instance, a 6-inch trench may be used for a 4-inch plastic pipe while a 15 or 18-inch trench will be required for a 6-inch cast iron pipe with 33-inch excavations for the bells. This often represents approximately a three-fold savings in excavation and backfill quantities.

*Also true for tubing and some pipe made of Type II PVC and PB.

Additional savings are sometimes possible through use of the technique of laying pipe by mole-plow. This technique, developed in England and now practiced successfully in the U.S. on large rural projects, employs a modification of the drain-type mole-plow which is either pulled directly behind a tractor, or, the tractor is anchored and pulls the plough towards it by means of a winch and a cable. Attached immediately behind the mole-plow is an expander larger than the overall diameter of the joints on the pipe and the leading end of the pipe to be installed is shackled to the back of the expander so that the pipe is installed as the mole-plow is pulled fowrard.

The mole-plow technique eliminates trenching but, although it is quick and economically attractive, ground conditions must be appropriate for the use of this method. A soil survey is essential before deciding to use it and other underground services, if any, in the area in which it is intended to lay the pipe must be identified and located.

Basis of Design

The hydraulic calculations required in pipeline design are brief. Once the maximum required capacity has been estimated it is only necessary to feed flow, head loss and estimated friction factor into an empirical formula or design chart to arrive at a pipe diameter. While for most pipe materials it is advisable to allow a margin of overcapacity for deterioration or buildup in the inner wall of the pipe, this is not the case with plastic pipe which is noted for maintaining its original flow characteristics. Generally a limiting maximum velocity of five feet per second is recognized.

Tables 7 and 8 are included to assist the designer in making preliminary calculations. Note that the inside diameters vary considerably from the nominal pipe size, for instance the ID for 1/2-inch PVC 200 pipe is 0.72 inches. The tabulated ID can be used with Hazen-Williams nomographs (Figure 6 for English units, Figure 7 for metric) to determine relative head loss, flow, or velocity. A Hazen-Williams "coefficient" of 150 is commonly used for plastic pipe.

In the United States there are three different physical sizing systems commonly used for plastic pipe. The Schedule system was the initial dimensioning system adopted by the plastics pipe industry. It is still in use today. It is based on outside diameters and wall thicknesses.

The newer* SDR-PR (standard dimension ratio-pressure rated) system differs from the Schedule system in that pipe of any size made to the SDR basis has the same pressure rating if made of identical material. That is, the user may purchase ABS or PVC pipe, for instance, with a 160 psi pressure rating in all sizes ranging from ½-inch to 6-inch diameters. Using the Schedule sizing system, this is not possible because of the decrease in pressure rating with increasing pipe diameter, i.e., there is not a constant relationship between pipe diameter and wall thickness as in the SDR system.

The third pipe sizing system, Tubing, is based on copper tubing sizes (outside diameter) and is associated with pipe made exclusively of PE, PVC,

*The diameter of a pipe divided by its wall thickness is its dimension ratio.

TABLE 7
MATERIAL REQUIREMENTS AND PIPE CLASSIFICATION FOR ABS, PE, AND PVC PIPE

Compound	Hydrostatic design stress (psi)	Pressure rating (psi)										
		SDR 7	SDR 9	SDR 11.5	SDR 13.5	SDR 15	SDR 17	SDR 21	SDR 25	SDR 32.5	SDR 41	SDR 64
ACRYLONITRILE-BUTADIENE-STYRENE (ABS)												
ABS 1106	630				100		80					
ABS 1210	1000				160		125	100	80			
ABS 2112	1250				200		160	125	100			
POLYETHYLENE (PE)												
PE 2305	500	125	100	80								
PE 2306	630		125	100		80						
PE 3206	630		125	100		80						
PE 3306	630		125	100		80						
POLYVINYL CHLORIDE (PVC)												
PVC 1120	2000				315		250	200	160	125	100	63
PVC 1220	2000				315		250	200	160	125	100	63
PVC 2110	1000				160		125	100	80	63	50	
PVC 4116	1600				250		200	160	125	100	80	50

TABLE 8

ILLUSTRATIVE DIMENSIONS AND PRESSURES FOR PLASTIC PIPE

Compound	ABS ABS 1210		PE PE 2306		PVC PVC 2110	
*Pressure Rating	SDR-21 100 psi		SDR-11.5 100 psi		SDR-21 100 psi	
Nominal Diameter inch	ID (inch)	Wall Thickness (inch)	ID (inch)	Wall Thickness (inch)	ID (inch)	Wall Thickness (inch)
½	-	-	0.622	0.060	0.720	0.060
¾	0.930	0.060	0.824	0.072	0.930	0.060
1	1.189	0.063	1.049	0.091	1.189	0.063
1¼	1.502	0.079	1.380	0.120	1.502	0.079
1½	1.720	0.090	1.610	0.140	1.720	0.090
2	2.149	0.113	-	-	2.149	0.113
2½	2.601	0.137	-	-	2.601	0.137
3	3.166	0.167	-	-	3.166	0.167
4	4.072	0.214	-	-	4.072	0.214
6	5.993	0.316	-	-	5.993	0.316

Source: U.S. Dept. Commerce Commercial Standards (See Appendix C).

*The SDR system makes possible a constant pressure rating over all diameters. For Class T, ABS 1210, the pipe pressure rating ranges from 250 psi (½-inch) to 50 psi (6-inch) and wall thicknesses vary from above. Similar variation exists for other Schedule sized ABS, PE, and PVC pipe.

or PB (polybutylene). The popularity of this system has greatly decreased with the advent of the SDR system. Its principal usage is in small wells equipped with submersible or jet-pumps.

There are numerous methods of joining plastic pipe and fittings. The major methods are described in some detail in Appendix H. It should be noted that plastic pipe and fittings can be readily joined to pipe and fittings made of other plastics materials or of non-plastic material. Specific information and procedures can be obtained from the pipe manufacturer or supplier.

Plastic pipe for water supply system use is available in a wide range of sizes. The largest diameter commonly maintained in stock is about 8-inch, with a few manufacturers stocking pipe up to 12-inch diameter. 16-inch diameter pipe is occasionally used in Japan and one British firm markets an 18-inch diameter pipe. The nature of the manufacturing process is such that equipment changeovers from inch to metric units is relatively simple for pipe production. The same cannot be said, however, for fittings. A few of the larger pipe manufacturers could probably produce pipe up to 48-inches in diameter if a demand arose.

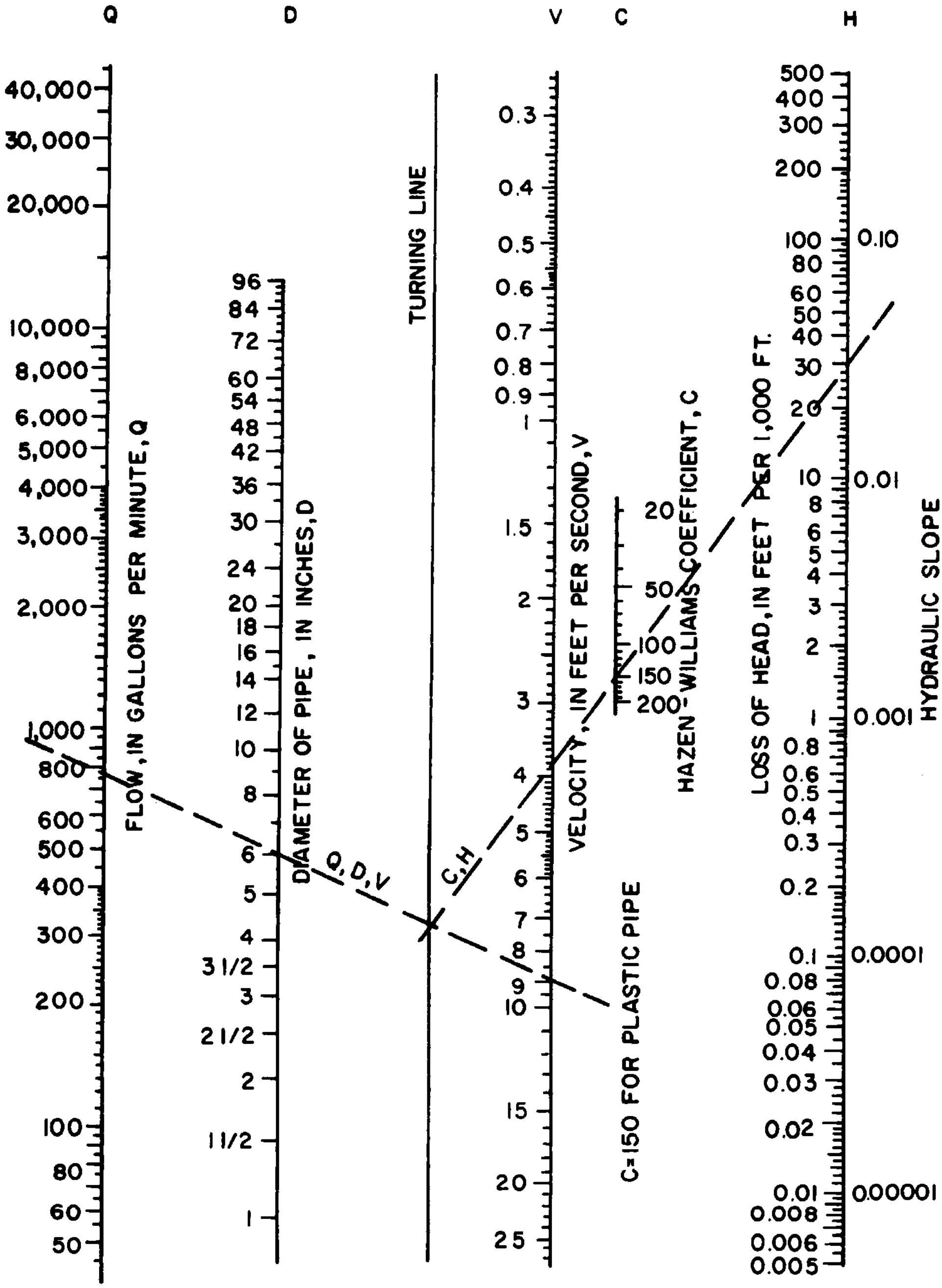

Figure 6
NOMOGRAPH FOR HAZEN–WILLIAMS EQUATION
(English Units)

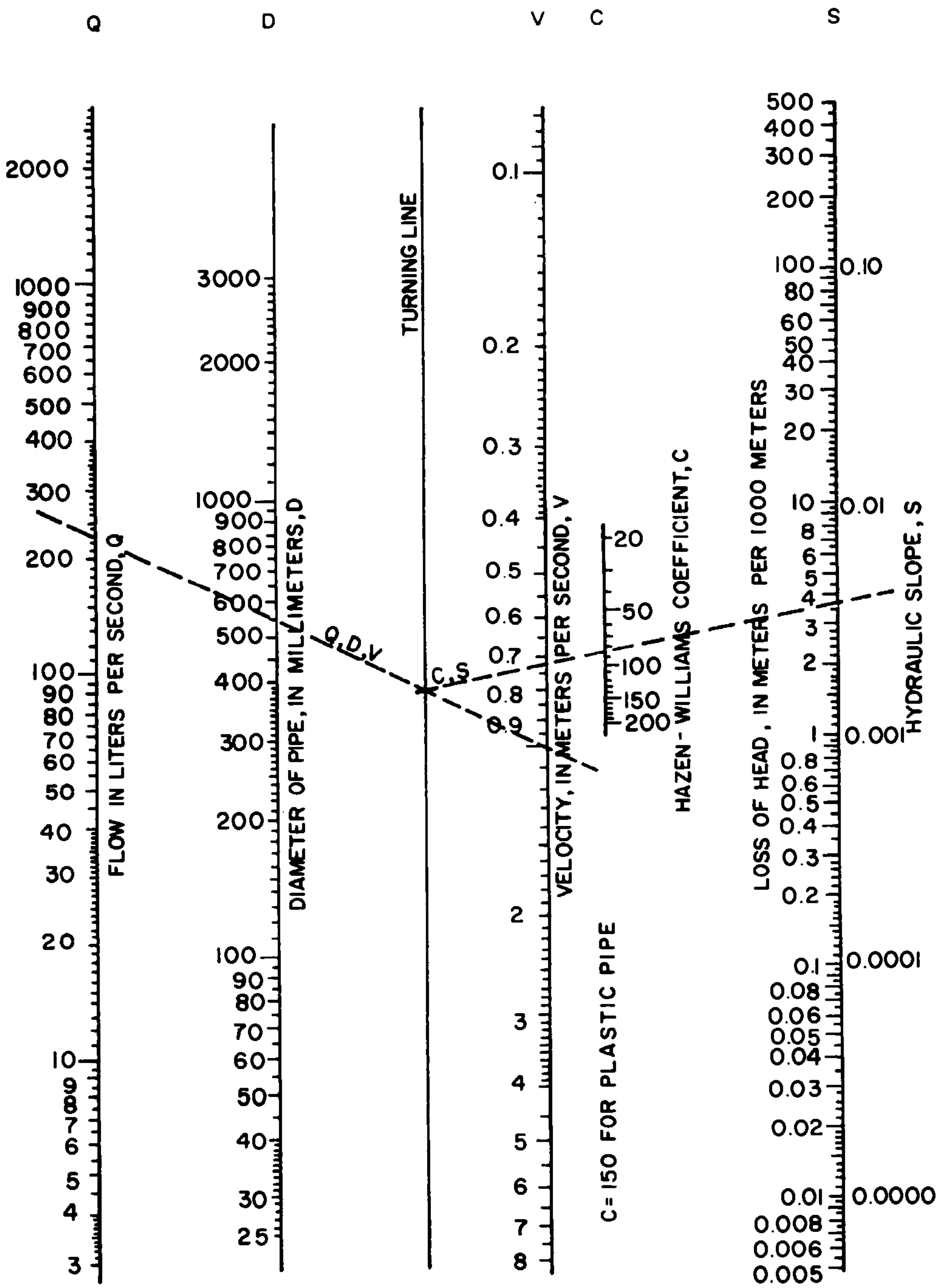

Figure 7
NOMOGRAPH FOR HAZEN–WILLIAMS EQUATION
(Metric Units)

Plastic pipe for water supply system use is available in a wide range of sizes. Those in English units are shown in Table 9.

TABLE 9

*AVAILABLE DIAMETERS (NOMINAL) IN PLASTIC PIPE

Pipe Diameter (inches)	½	¾	1	1¼	1½	2	2½	3	3½	4	5	6	8	10	12	16
ABS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
PE	X	X	X	X	X	X	X	X		X		X				
PVC	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

*There are smaller sizes available but these are not used for house service lines. Larger sizes of plastic pipe may be obtained (up to possibly 48-inch diameter.) There are some exceptions to the above listing in some of the SDR categories particularly in ABS and PVC pipe.

For some years the major technical problem in the design of thermoplastic pipe and in preparing satisfactory specifications for these products has been the selection of hydrostatic design stresses for long-term applications such as are required for water and gas distribution systems both inside and outside buildings. Short-term burst and other properties measured during short-term loading have been shown repeatedly to be unreliable for this purpose.

Members of the plastic pipe industry operating through the Plastics Pipe Institute developed a method for determining hydrostatic strength and design stresses for thermoplastic pipe from engineering test data and with the cooperation of approximately 45 laboratories analyzed over 800 sets of engineering test data. Recommendations were developed for hydrostatic design stresses for water at 23° C (73° F) for a number of plastic pipe materials. Some of the more common are shown in Table 10. European design stresses have been added to the table by way of comparison. Their basic compounds may be different from U. S. compounds (different formulation).

Plastic pipe is pressure rated at a standard temperature of 73.4° F and pressure rating decreases with temperature increase until a critical point is reached, depending on the specific compound. Temperature for pipe in buried applications is not critical for most situations once the pipe is buried and full of water as water temperatures generally run near or below 100° F. The critical time for temperature consideration is during installation periods.

All of the thermoplastic materials used in the manufacture of pipe have a greater degree of expansion and contraction due to temperature variations than steel pipe. This movement is independent of the diameter of the pipe. Table 11 is illustrative.

TABLE 10

HYDROSTATIC DESIGN STRESSES AND 50-YEAR STRENGTH DATA

Water at 23°C (73°F)

	Hydrostatic Design Stress psi.	50-Year Strength psi.	100,000 Hr. Strength psi.	*European Hydrostatic Design Stress psi.
PVC 1120	2000	4010	4250	1400
PVC 1220	2000	3790	4070	1400
PVC 2110	1000	2110	2370	
PVC 2116	1600	3620	3800	
PVC 4116	1600	3640	3800	
PE 1404	400	820	870	425
PE 2305	500	1000	1090	425
PE 2306	630	1230	1300	710
PE 3206	630	1200	1280	710
PE 3306	630	1270	1350	710
ABS 1208	800	1440	1670	
ABS 1210	1000	1890	2070	
ABS 1316	1600	2930	3160	
ABS 2112	1250	2260	2510	
CAB MH08	800	1450	1580	

*The hydrostatic design stresses used for plastic pipe in Europe are 50-year strength predictions obtained on an entirely different basis than those shown above and divided by a factor. A move is underway (1965) to raise the 1400 ratings to 1800 psi.

TABLE 11

TEMPERATURE EXPANSION AND CONTRACTION OF PLASTIC PIPE

Material	Coefficient (in/in/°F)	Expansion and Contraction (per 100 ft. per 10°F Temperature Change)
PVC – Type 1	4.1×10^{-5}	0.492 inches
PVC – Type 2	5.3×10^{-5}	0.636 inches
ABS – Type 1	5.7×10^{-5}	0.684 inches
PE – Types 2 and 3	8.9×10^{-5}	1.068 inches

Techniques for handling this expansion are outlined in Appendix H.

Protection of Health

Another important specification is assurance that plastic pipe presents no public health hazard.

In addition to the basic resins, plastics compounds ready for extrusion contain certain additives. A brief consideration of these additives in pipe will clarify the reason for concern about the suitability of plastic pipe, particularly PVC pipe for potable water use.

The formulated compound from which PVC pipe is made contains pigments, lubricants and stabilizers in addition to the basic polymer, polyvinylchloride. The pigment is incorporated to render the pipe opaque and, in water pipe, carbon black or titanium oxide is commonly used for this purpose. Lubricants serve to reduce the adherence of the pipe material to the extrusion tools during the manufacturing process and quite a range of materials are used for this purpose including stearic acid, calcium stearate, glycerol monosterate, polyethylene wax and montan wax. Stabilizers are incorporated in PVC compounds because the temperatures used for extrusion and injection molding (100° to 200° C) are such that detrimental decomposition of PVC takes place with the liberation of hydrogen chloride. In the presence of oxygen the reaction is autocatalytic, but it can be reduced to a slow uniform rate by the incorporation of a substance that can effectively remove the hydrogen chloride as it is formed. White lead, for example, a basic lead carbonate that is commonly used as a stabilizer has been shown to react in this way. During the heat processing of PVC compounds, it is converted to lead chloride.

Many other substances have been used as stabilizers including compounds of lead, cadmium, borium, tin, calcium, and zinc. In contrast to the polymers, pigments, and lubricants, which in general are physiologically and chemically inert, many of these stabilizers are toxic or suspect.

The choice of a stabilizer is dictated by technical and economic considerations. A well-stabilized PVC compound produces a pipe with better stress characteristics and impact resistance than one in which the stabilization is inferior. Unfortunately however, many of the non-toxic stabilizers are markedly less effective in performance or are much more expensive than stabilizers based on, for example, lead compounds.

Lead stabilizers are by far the most widely used in PVC extrusion generally, but are not used in the United States in pipe intended for potable water use. Lead stabilizers are used, however, in pipe manufactured in Europe and in Japan and intended for potable water use. Tin stabilizers are the leading stabilizers, in frequency of use, for water supply pipe manufactured in the United States. Their cost per pound is about four times that of lead stabilizers.

Tin stabilizers are widely used in the production of pipe fittings, including drain, waste, and vent (DWV) piping, by injection molding, products where the material costs are less important as part of the cost of the final product.

Numerous investigators* have shown that lead stabilizers and their reaction products can transfer to and dissolve in water in contact with PVC.

*Boelens, Boone, Bracale, Chuy, Donovan, Niklas and Meyer, Tiedemand and Milone, *et al.* See Appendix B for complete bibliographic references.

The extractable lead in a PVC pipe is apparently confined to a surface film that is rapidly removed as the pipe is flushed out. In several static experiments on PVC pipes filled with water, the majority of the lead was given off in the first two or three days of standing. After this time leaching rapidly decreased and showed little further change after ten or fifteen days. The total quantity of lead extracted in this period is small relative to the total initial lead content of the pipe. Migration of lead from the bulk of the PVC apparently takes place slowly, if at all. If the pipe is pre-treated with certain acidic solutions, the film of lead stabilizer may be completely removed; subsequent extraction of the pipe with water gives no trace of lead even after a period of several months contact.***

Concern about possible leaching of lead from plastic pipe is due to lead's history as a cumulative poison which tends to be deposited in the bones. Lead poisoning usually results from cumulative toxic effects of lead after continuous consumption over a long period of time, rather than from occasional small doses. Immunity to lead cannot be acquired, but sensitivity to lead seems to increase. The intake that can be regarded as safe for everyone cannot be stated definitely because the sensitivity of individuals to lead differs considerably.

Lead may enter the body through food, air and tobacco smoke as well as from water and other beverages. Consequently the total intake of lead must be considered in setting standards for water. The exact level at which the intake of lead by the human body will exceed the amount excreted has not been established but it probably lies between 0.3 and 1.0 milligram per day. The mean daily lead intake by adults in North America is about 0.33 milligram per day. Of this quantity, 0.01 to 0.03 milligram per day is derived from water used for cooking and drinking. A total intake of lead appreciably in excess of 0.06 milligram per day may result in accumulation of a dangerous quantity of lead during a lifetime. Lead in an amount of 0.1 milligram ingested daily over a period of years has been reported to cause lead poisoning.

For many years the mandatory limit for lead in the U.S. Public Health Service Drinking Water Standards was 0.1 milligram per liters; however, owing to the fact that the total intake of lead from food, inhaled atmosphere and tobacco smoke in industrial urban areas appears to be increasing with little chance of regulation and diminution, and inasmuch as the concentration of lead in drinking water can be controlled without undue hardship on water purveyors, the USPHS Drinking Water Standard for lead was lowered in 1962 to 0.05 mg/litre. It is significant to note that the U.S. Government has also established a tolerance of lead in food at 7 milligrams per kilograms, more than 100 times the limit for drinking water.

The limit of 0.1 mg/liter in the WHO International Standards for Drinking Water was lowered to 0.05 mg/liter in 1963. In the past the Netherlands and

***Research now in progress at the National Sanitation Foundation, Ann Arbor, Michigan, U.S.A. *directly contradicts* these earlier studies. The authors of this report are grateful to Mr. Charles Farish for bringing these studies to our attention. Concerned readers are advised to contact Mr. Farish directly.

Germany have permitted a temporary lead concentration up to 0.3 mg/liter in water that has been in pipes for 24 hours. Uruguay, on the other hand, has used a standard as low as 0.02 mg/1. Several countries use 0.1 mg/liter as a standard. The British Standard 3505 amended in 1966 specifies that lead extracted from the internal walls of PVC pipe shall not exceed 1.0 mg/liter in the first wash and 0.3 mg/liter in the third wash. It states that conformity with this will ensure that the 1963 WHO recommendations concerning toxic contaminants of drinking water are not exceeded. The 1964 standards of Israel have a similar standard.

Some countries minimize the health hazards resulting from the use of plastic pipe by regulating the type and quantity of stabilizers that may be incroporated into the pipe material. For instance Peru specifies that only calcium and zinc may be used as stabilizers for pipe to be used in potable water installations. However, tests conducted in Peru (Bracale, Chuy) in 1967 lead the researchers to conclude:

(1) For PVC pipe stabilized with lead the concentration of lead in the extracting water is extremely low and is much below that permitted by the standards for potable water.

(2) The quantity of lead extracted decreases with time; it having been proved experimentally in the laboratory and by analysis of samples taken from distribution systems that the total amount of extractable lead is depleted in a period no greater than 90 days.

(3) It is considered that these pipes under normal service conditions offer no risk whatever to the health of the users of the potable water systems.

It is not known whether the standards in Peru have been changed accordingly.

In the United States the ASTM specifications for Plastic Pipe include a note stating the . . ."pipe to be used for the transportation of potable water should be tested and approved for that purpose by the regulatory bodies having such jurisdiction. Information regarding the special requirement for such pipe can be obtained from the National Sanitation Foundation Laboratory or other accredited laboratory." Standard No. 14 of NSF states . . ."The toxicological and organoleptic evaluation of the analyses specified in appendix B shall meet minimum public health requirements . . ." and Appendix B.2 reads, . . ."The maximum acceptable concentrations of chemical substance permissible in the extractant water shall be as set forth in Public Health Service Drinking Water Standards - namely 0.05 mg/liter."

The NSF, after extensive tests of the extractant water from plastic pipe made with lead stabilizers, has concluded that data acquired to date do not support the use of lead stabilized plastic pipe for transporting potable water. All pipe formulations now approved by NSF contain no lead stabilizers.

Whether the use of toxic stabilizers in plastic pipe is controlled by direct limitations on the composition of the pipe material or by standards limiting the amount of extractable material present, the ultimate objective is to insure that the quality of the drinking water that comes into contact with the pipe will not be adversely affected in any way that is injurious to health.

It is suggested that the developing countries will want to consider all of the many factors involved before deciding on the controls they may wish to establish for plastic pipe stabilizers to insure the quality of water passing through those pipes. One of the first considerations is the amount of lead being ingested already from other sources such as food and air. If this is comparatively low the decision may be reached to allow the use of lead stabilizers with controls limiting the extractable material present in the water as is done in Great Britain, the Netherlands, Germany, Israel, Japan and some other countries. The use of lead stabilizers will probably make it possible to lower the cost of the plastic pipe and may also produce a pipe with better stress characteristics and impact resistance. These will be important considerations in developing countries where funds are extremely limited and much remains to be done to provide adequate water supply and sewerage services.

The cost differential is difficult to determine. Lead stabilizers cost $0.35-0.40 per pound versus about $1.50 per pound for tin. Tin stabilizers run around $0.02 per pound in extruded PVC pipe. However the lower specific gravity of tin eliminates possibly half of lead's price advantage. Extruder retention time and temperature, extruder design, output rate, compound synergism, length of runs, level of regrinding, *et al*, all play a role in prohibiting direct cost comparison. All aspects considered, the use of tin, rather than lead costs an additional $0.01-0.02 per pound, more or less. This may seem insignificant as a percentage of installed cost (negligible to 2 percent depending on diameter, pressure rating, and installation costs), but may represent as much as 25 percent of the producer's profit margin. Thus non-lead stabilized pipe will not be competitive in an unrestricted market.

Incidentally, U.S. plastic producers have sold both lead and non-lead stabilized compounds to overseas pipe manufacturers.

The Central Public Health Engineering Research Institute (CPHERI) Nagpur, India recently investigated (a) the bacteriological quality of water transported through PVC and PE pipe; (b) whether the plastic pipes harbor larger numbers of bacteria on their interior surfaces; and (c) whether problems of disinfection are encountered with the pipe. The experiments were designed to test whether any nutrient materials could be released to water from plastic pipe, under normal conditions, which might support the growth of bacteria, particularly under tropical conditions. In the studies no significant increase in the number of bacteria was observed in water passing through or stagnant in PE and PVC pipe as compared to those of galvanized iron and asbestos cement pipes.

The experimental findings were that plastic pipes neither harbor large numbers of bacteria on their internal surfaces as compared to other pipe materials nor do they pose problems in disinfection. From a bacteriological point of view it was concluded that plastic pipes are safe for use in India in the conveyance of potable waters.

Tiedeman and Milone* reported that plastic pipe systems can be satisfactorily disinfected following standard disinfection procedures. In experiments using high concentrations of chlorine on various plastic pipe materials, no adverse effects were noted on the plastics after 20 hours exposure at 10° C. Adverse effects on copper and galvanized steel specimens were noted, however, when they were held under similar conditions. Higher than usual concentrations of chlorine may be used in the disinfection of plastic pipe without damage.

The same report points out clearly that there is no evidence that rats eat plastic pipe nor that they gnaw it in preference to other substances. It was found that rats could gnaw through plastic, lead or copper pipe when any of these presented a barrier to food or water. PE pipe was slightly more susceptible than other plastic pipe, possibly because of the softer nautre of the pipe. There is no evidence of rats attacking ABS pipe in any of the more than 1½ million DWV residential installations made up to 1967.

Plastic pipe also resists attack by bacteria, fungi, and termites. (A literature review may be found in PPI Technical Report 11*).

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*See Appendix B for bibliographic citations.

V

MANUFACTURE OF PLASTIC PIPE

Introduction

Plastic pipe is made by extrusion of compounded thermoplastic materials through specially designed annular dies, followed by take-off and postforming equipment to size, calibrate, cool, and cut the pipe. A typical extruder consists of a rotating screw enclosed in a cylindrical barrel. The proper combination of screw, barrel, and heating-cooling system should produce a fully plasticated, thermally homogeous melt, and uniform flow rate through the die.

The material, in pellet or powder form, is fed from a feeding mechanism (hopper) into the machine cylinder. One or more longitudinal screws rotating inside the heated cylinder forces the heated plastic through a die orifice which has approximately the shape of the pipe. The heated cylinder and rotating screw work to produce a completely plasticized and thermally homogeous fluid, provide the force necessary to extrude the material through the die, and maintain the material at uniform termperature, viscosity, homogeneity and velocity through the die. (See Figure 8).

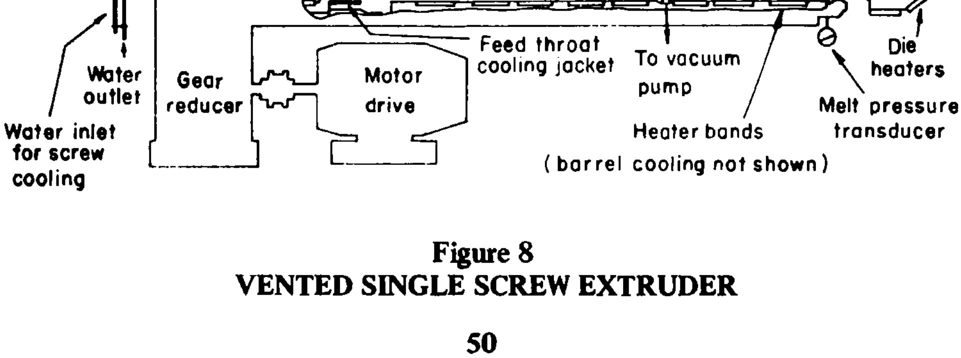

Figure 8
VENTED SINGLE SCREW EXTRUDER

Pipe sections are extruded with undersized diameters (internal and outside) and inflated as they leave the die orifice. The technique has a two-fold purpose - as well as producing pipe of accurate diameter it provides a simple method of preventing the tube from collapsing while hot.

Sizing can be achieved by supplying compressed air to the extrusion through the die head or by applying a vacuum to the outside of the pipe, as the extrusion passes through a cooled sizing die. Use of compressed air is cheaper and easier, vacuum sizing is more accurate.

Extruders

Extruders are available with either single or multiple screws which can be vented for removal of volatiles. The vent can be plugged and, normally, the screw changed for non-vented operation. Vented single or multi-screw extruders are useful to remove volatiles from resins, such as monomers, moisture, and trapped air which might otherwise cause bubbles or other defects in finished parts. The vented extruder is sometimes more difficult to design and operate due to the balancing necessary to avoid plugging or escaping from the vent. The vent can be operated at atmospheric pressure, but vacuum is more common.

Extruders are specified by barrel inside diameter (ID), length to diameter ratio (L/D), and capacity. Standard sizes of the single screw extruder are 1½, 2, 2½, 3½, 4½, 6 and 8 in. ID, with larger diameters available on special order. The general relationship of extruder size to pipe size is shown in Table 12.

TABLE 12

EXTRUDER SIZES COMMONLY USED IN MANUFACTURE OF PLASTIC PIPE

Pipe Size	Extruder Size
½" to 2"	2½"
1½" to 8"	3½"
4" to 16"	4½"

The average output for a variety of plastics and applications increases with extruder diameter and L/D, as shown in Figure 9. Actual output can differ depending on compound, drive hospower, screw design, screw speed, termperature limitations, etc.

The L/D ratio, defined as the screw length with flights divided by barrel ID, has an important relation to available barrel surface area and residence time of the plastic within the extruder. The calculation of L/D is not standard, as some count only the flighted length of the screw after the feed hopper section, and others the entire flighted length. The difference usually is about 1.5 diameters. An L/D of 24:1 is quite popular, although ratios of 16:1 to over 30:1 are available. The trend has been to higher L/D to achieve higher outputs and better uniformity.

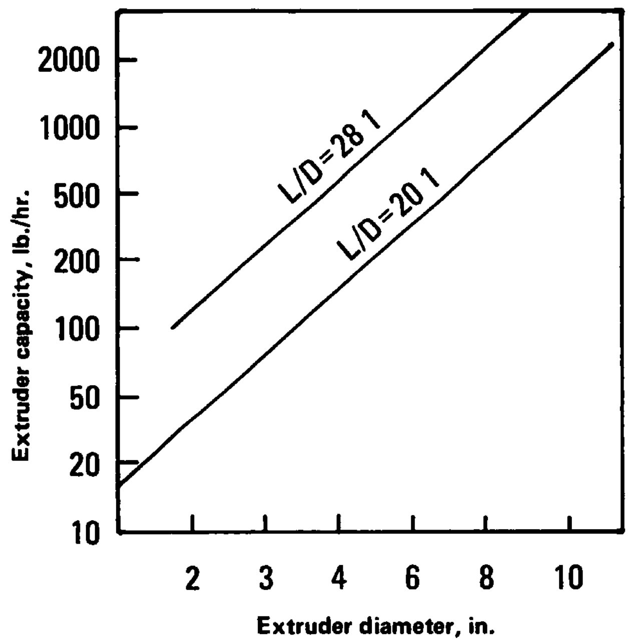

Figure 9

AVERAGE EXTRUDER OUTPUT

The hollow cylinder, or barrel, in which the screw turns is usually designed to withstand 10,000 p.s.i. Wear resistance and hardness of the barrel interior are generally provided by nitriding in Europe, and by alloy liners (usually "Xaloy") in the U.S. Higher pressures often require shrink fitting a steel tube with a cast-in liner into an outer barrel. Special corrosion resistant formulations and various thicknesses of lining are available.

Most extruders have heating and/or cooling provisions on their barrels to adjust operating conditions. Heat is most often applied by external electrical resistance or induction heaters arranged in several groups or zones along the barrel.

Cooling of the extruder barrel is sometimes required to permit rapid changes in temperature, or to remove excess heat from the polymer melt. High output extruders usually receive most of their heat from the screw, rather than from the barrel heaters, once the extruder is in operation. Sometimes the screw working adds too much heat, especially at higher screw speeds, and the ability to cool can extend the capability of the extruder.

A screenpack is placed just after the screw to remove gross contamination from the melt stream. It often has several wire screens in series. The screenpack is backed by a breaker plate which has a number of passages, usually many round holes ranging from 1/8-3/16-inch diameter. The breaker plate serves as a seal between the extruder and adapter, as a support for the screens, and to reduce the circular motion of the melt.

Other elements required include a motor drive, preferably with variable speed; a gear transmission which permits operation of the screw in its proper range of speed; a thrust bearing assembly to absorb the screw thrust; and monitoring devices for melt temperature and pressure, screw speed, power consumption, and product dimensions.

Many plastics absorb moisture or contain volatiles or entrapped air which may result in surface blemishes, porosity or roughness of the extruded pipe. Vented extruders with two-stage screws permit continuous removal of these volatiles but non-vented extruders require that the materials be predried in ovens or hopper driers. Reference is made to both types of equipment in the section on equipment costs, one with hopper driers and the other with a vented screw.

Another accessory essential for efficient operation of a plastic pipe plant is a machine for grinding plastic material. Plastic pipe or fittings found dimensionally defective may be ground up and mixed with new material of the same type, density and general specifications to produce new pipe and fittings. All such material must be properly identified to prevent mixing materials with different characteristics. Addition of low grade materials to higher specification mixes has led to the production of pipe which has failed and was responsible for many criticisms of plastic pipe for potable water use.

Some manufacturers prefer to process the ground material through the extruder first and then pass it through a granulating machine to make pellets of a uniform size which may be mixed with new material for use in the extruder.

Manufacture of Fittings

The accessories, connections and fittings used with plastic pipe are generally manufactured with the same type of material used for the pipe, using *injection molding.* The extruder melts and pumps the hot plastic material directly into molds. The molds may be arranged on an indexing mechanism such as a vertical or horizontal turntable or may be located in stationary clamping mechanisms. In the latter case the plastic is pumped through valved manifold outlets which open and close in sequence. Many different modifications of the injection molding method are being developed and perfected for more economical production of the fittings used with plastic pipe.

The design and production of fittings is much more complex, difficult, and costly than is pipe. Many U.S. manufacturers make pipe but not fittings. Few of those who make fittings make their own molds, the key to successful fittings production. As an industry rule of thumb, a good line of molds for drain, waste, and vent fittings (tees, elbows, etc.) will cost a million dollars. The design and machining of molds for pipe fittings in the U.S. is dominated by only three firms and considering the experience and capital required and the size of the market, the outlook for additional firms in the market is not promising. Incidentally, all three U.S. moldmakers lease molds to overseas affiliates.

Basic Materials

Basic compounds, except PVC, are not generally manufactured by pipe producers but are purchased from the chemical industry. Most plastic materials used for pipe extrusion are purchased either in pellets or fine powder. They may be obtained in 50 pound bags, 200 pound drums, in 1,000 to 2,000 pound boxes or even in sealed tanks containing commonly 30,000 pounds (truck lot) of material.

Many operators feel that plastic material in the form of pellets is more advantageous than in the powder form. The pellets are cleaner to handle and produce less dust in the feeder hopper. They tend less to clog the extruder. If the powder form is used it is advisable to install a vacuum hopper to reduce air entrapment in the extrusion. Unless the extruder is ventilated this air may pass through the extruder and appear in the pipe as imperfections or surface bubbles.

Stabilizers, plasticizers, lubricants, pigments, and other additives are mixed with the resins before pipe extrusion. These may be added by the pipe producer or the resin supplier. The mixed materials, ready for feeding the extruder, are known as "formulated bulk compounds."

The U.S. price range for materials is shown in Table 13.

TABLE 13

MATERIAL PRICES FOR PLASTIC PIPE*

Compound	Basic Resin	Formulated Bulk Compound
PE	10½ - 11¢ lb.	19½ - 21½¢ lb.
ABS	-	28 - 33¢ lb.
PVC	10 - 12¢ lb.	13 - 22¢ lb.

*Based on representative quotations. Price increases with pressure range.

Equipment Costs

The outstanding favorable characteristic of basic plastic pipe production is the low capital investment required for manufacture of small-diameter pressure pipe, as little as $50,000 according to industry sources. A recent quotation on a facility for production of ½-inch through 4-inch diameter pipe illustrates detailed costs for an actual facility:

Item No.	*Specification*	*Cost*
1	Extruder: 2½-inch bore, 24:1 L/D with horizontal gear case vented with solid vent plug.	$12,800
	A. Crown shaven helical gearing having a double reduction of 17.21:1 rated at 66 HP 100 RPM and a service factor of 1.25. Open gap ring to provide	

Item No.	Specification	Cost
1 *(cont.)*	thermal isolation between the gear case and feed section and to allow easy access to feed section bushing or seal. Feed section is jacketed for water cooling, having a round center opening greater than the barrel bore and an oversize hopper of stainless steel with shut-off, level indicator and dump chute. Water piping and catch installed. One piece alloy steel barrel with integral Xaloy liner. Front flange to be quick opening clamp type with dual swing bolt clamp. Barrel heated with therma-fin heaters in 5 zones, 5 KW per zone and cooled by ½-HP blower in each zone capacity at 1¼ inches static pressure of 325 CFM per zone. Heater voltage 220 volts. Barrel covered by insulated hood. Extruder mounted on base of modular design providing for a centerline height of 42¼ inches. Accessories include: plugplate; head hinge support; stock screw cooling pipe with rotating union; breaker plate; pressure gauge installed on barrel; stock screw removal jack assembly; motor base, bolts and sheaves and vacuum compactor.	
	B. Vent Plug - slotted vent plug for operating extruder under vented condition.	$ 240.
	C. Compactor - vacuum compactor feed hopper. Constructed of heavy gauge stainless steel in a conical shape with air tight cover rigidly supported to feed section of extruder and reinforced for vacuum operation. Vacuum is maintained by a vacuum pump included with compactor.	$ 7,145.
	D. Mixing Screw - 2½-inch 24:1 mixing screw with single flight cored for cooling, electrolized with standard removable tip.	$ 2,060.
	E. Pipe Head - PVC pipe head complete with one size and one schedule of tooling - ½-inch through 2-inch capacity. Includes head to extruder adapter.	$ 3,000.
	F. Pipe Head - PVC pipe head complete with one size and one schedule of tooling - 2-inch through 4-inch capacity. Includes head to extruder adaptor.	$ 5,000.
2	Two-Stage Vacuum Sizer and Vacuum Pump - with stainless steel tank and sump.	$ 2,700.

Item No.	*Specification*	*Cost*
	Sizing Sleeves, ¾-inch, 1-inch through 1½-inch, 2-inch through 4-inch.	$80 to $125 each size.
3	20 foot open immersion cooling tank to 6-inch nominal size.	
	Stainless steel construction.	$ 2,400.
4	Take-off Unit Capacity to 8-inch nominal plastic pipe	$ 4,225.
5	Automatic traveling cut-off saw, capacity ½ inch to 6 inch.	$ 2,210.
6	Temperature control unit for extruder 7	$ 1,800.
7	Independent extruder and compactor drive with combination drive and heater panel--aircooled eddy-current--adjustable torque, speed limited compactor drive.	$14,600.
	TOTAL ESTIMATED PRICE FOB CONNECTICUT	$56,580.

A 3½-inch extruder, capable of producing 6-inch pipe would cost about 50 percent more than the 2½-inch extruder just described. Similarly a 4½-inch extruder would cost about 100 percent more. With the appropriate pipe head, the larger extruders can, of course, also produce smaller diameter pipe and at higher output rates. Table 15, showing extrusion rates, time, and labor for an ABS pipe facility, is illustrative. Output also depends on the compound being extruded. Table 14 is illustrative.

TABLE 14

COMPARATIVE PRODUCTION

NOMINAL OUTPUTS AT MAXIMUM SPEEDS IN POUNDS PER HOUR

Extruder Size	L/D	PE	PVC	ABS
2½ inch	23/1	190	270	160
3½ inch	24/1	370	550	310
4½ inch	25/1	555	840	430

Source: Bulletin 483 11-63, Royal Spirod Extruders, John Royle & Sons, Paterson, New Jersey.

TABLE 15

EXTRUSION TIME AND LABOR FOR ABS PLASTIC PIPE (Class 40 IPS)*

Nominal Diameter Inches	Outside Diameter Inches	Wall Thick- ness Inches	Weight lbs/ 1000ft	2½ inch Extruder		3½ inch Extruder		4½ inch Extruder	
				Machine Hours Per 1000 feet (140Lb/ hr)	Man Hours Per 1000 feet (1.5 men/ hr)	Machine Hours Per 1000 feet (210Lb/ hr)	Man Hours Per 1000 feet (1.5 men/ hr)	Machine Hours Per 1000 feet (320Lb/ hr)	Man Hours Per 1000 feet (1.5 men/ hr)
1	1.315	0.133	222	1.6	2.4	1.05	1.6	1.5	2.3
1¼	1.660	0.140	301	2.1	3.2	1.4	2.1		
1½	1.900	0.145	360	2.6	3.9	1.7	2.6		
2	2.375	0.154	485	3.5	5.2	2.3	3.5	1.5	2.3
3	3.500	0.216	1005			4.8	7.2	3.1	4.7
4	4.500	0.237	1430			6.8	10.2	4.5	6.7
6	6.625	0.280	2520			12.0	18.0	7.9	11.8

*From Farish, "Tuberias Plasticas."

None of the above prices includes the cost of such articles as hand tools, storage racks, equipment for handling material, and other items necessary for operation of the plant. The price of equipment required for injection molding of fittings is also not included.

A partial list of manufacturers of extruders, molds, and other equipment required in the production of plastic pipe and fittings is included in Appendix F.

Space Requirements

The following table is given to assist in estimating the space required for a plastic pipe plant. It is based on the space required for each extruder and should be multiplied by the number of extruders of each size to be installed. Space is provided for storage of the raw material required for two weeks production per extruder plus the space for storing the pipes produced. No space is included for office, laboratory, tool storage, or personnel. Provision should be made for these needs as well as for possible future expansion of the facilities.

TABLE 16

SPACE REQUIREMENTS IN SQUARE FEET

Extruder Size	2½ inch	3½ inch	4½ inch
Space for each extruder	75 x 16 = 1200	80 x 18 = 1440	85 x 20 = 1700
Storage for 2 weeks supply of raw material	1,000	1,500	2,300
Storage for raw material at extruder	400	600	800
Storage for 2 weeks pipe production	800 to 1,000	1,200 to 1,500	1,800 to 2,250
Total for each extruder	3,600	5,040	7,050

Labor Requirements

The basic manpower requirement for extruder operation is one skilled operator plus a laborer. With multiple extruder operations, one laborer can service several machines, resulting in some economy of scale. With a limited number of employees, one operator can serve as foremen. Management, sales, and other overhead personnel will be required commensurate with the scale of the business. A laboratory technician will be required for other than dimensional tests.

American industry has demonstrated its interest and willingness to open its doors to AID or WHO–sponsored international participants for observation and experience. Some U.S. firms are directly providing "knowhow" to affiliated overseas firms or through technical assistance and training to equipment or resin purchasers.

Formal training is also available in the U.S., ranging from one-week short courses (International Plastics Industry Consultants, Inc., Hotel Manhattan, N.Y., N. Y. 10036; courses offered in New York or on-site), to one- and two-year technician training programs at several colleges and technical institutes, to regular college curricula in plastics technology.

Primary Production of Plastic Resins

Generally in the developing countries the raw materials for extruding plastic pipe will be imported. However some of the larger countries with petro-chemical developments, e.g., Brazil, may be producing or considering the production of the raw material. In a plant-investment cost study, there are three categories for capital projects: grass-roots, new unit on an established site, and enlargement of an existing unit. The data quoted below are based on the second category--i.e., a production unit constructed on a previously developed plant site. If the plant fell into the so-called grass-root category, the total cost would have to include all off-site facilities such as utility buildings, general services, etc., and the final investment figures would be roughly 30% to 40% more than those shown. The third major category which is simply the enlargement of an existing plant is 20% to 30% less than for the category shown.

TABLE 17

CAPITAL COST DATA (1967) POLYETHYLENE PLANTS***

Compound	Typical Plant** Size Tons/Yr.	Investment Cost (Dollars)	Investment Cost/Annual Ton	Size* Factor "L"
Polyethylene				
High Pressure	200,000	14,000,000	70	0.70
Low Pressure	50,000	22,000,000	440	0.70

* "L" = Lang Factor. To obtain investment for a capacity other than the one shown, multiply the stated investment cost by the ratio of the desired capacity to the stated capacity, raised to the power "L".***

** Compared with total U.S. production (1967) of all types of PE pipe of about 50,000 tons (PPI estimates). Total U.S. PE plant capacity (1969) exceeds 3,000,000 tons (*Modern Plastics* estimate).

***Source: Haselbarth, J. E. "Updated Investment Costs for 60 Types of Chemical Plants." *Chemical Engineering,* Vol. 74, pp. 214-215 (December 4, 1967).

A decision to build a basic resin plant in a developing country will have to be supported by a wider market than that for pipe alone. Considering the high capital investment required and the major economies of scale in plant size, the market in any developing country is too small to sustain a basic resin plant solely on sales to the pipe industry (assuming competition with world resin prices). However in some countries with larger populations (or regional markets), petroleum resources, and reasonable hope of economic development, primary production exists or can be anticipated.

Minimum Feasible Plant Size For Pipe Manufacture

The following is based on a Plastic Investment Survey of the Philippines, Taiwan and Thailand prepared in 1963 for the Agency of International Development. Company X of the U.S.A. is currently earning net profits after taxes in excess of 10 percent on investment capital and can find additional domestic applications for funds which will provide this return in existing business. Therefore any foreign investment must necessarily provide a return on invested capital equal to domestic alternatives plus an additional risk increment. Therefore any investment consideration must return on investment capital a minimum real (constant dollars) profit of 15 percent per year. The desired return is 20 percent.

Absolute return is just as important as rate of return since total dollar profits must be sufficient to justify the owner's time and effort for entering the project. Therefore the potential yearly profit returns after taxes, determined rather subjectively, must be at least $100,000. This indicates that the firm should not enter into a project requiring an investment less than $700,000. Such a facility would have a capacity of 1,000 ton/year.

An economic plant size is important for technological reasons also. The economics of scale in plastics fabrication and distribution indicate a minimum plant of 500 tons/year capacity for PVC pipe. Sizeable continuous runs are also important in injection molding to justify the cost of expensive quality dies and to minimize set-up time in change-over.

Also essential is that the proposed plastic pipe project have the support of the foreign government officials and qualify for preferred status under the investment laws. The availability of AID political insurance is also important. Finally it is necessary that the factors of production be available on suitable terms.

According to the estimates in Table 14, one 3½-inch extruder would produce approximately 500 tons of PVC pipe in a year of 230 eight-hour working days, two 3½-inch extruders would produce 1,000 tons per year.

V

MARKET FOR PLASTIC PIPE

Demographics

The potential markets for plastic pipe in the developing countries dwarf the domestic U.S. market. In addition to the extensive market for pressure pipe for water supply, the potential use of plastic pipe in irrigation, gas, electrical, and sewerage installations is largely untapped.

Table 18 approximates the current water supply status of the developing world. The tabulation shows only numbers served but gives no indication of the quality of service nor of how many of the services badly need inprovement.

A brief analysis of the information reveals that Northern Africa and Latin America are roughly comparable in percentage of people served, 45 percent and 46 percent respectively. The Near East and South Asia are at the other end of the scale with probably less than 16 percent of the population served in both areas.

While percentages are interesting, the estimated numbers of people without water supply service are revealing from the point of view of need for pipe and fittings. Of the roughly 1.5 billion people in the developing world, more than a billion do not have water supply service either by house connections nor from public outlets. This demonstrates the urgent need for water supply systems designed to provide services at the lowest possible cost. Any saving in per capita cost is multiplied by millions in overall savings. Plastic pipe offers one way of cutting these costs, particularly in the smaller sizes. When savings in handling and installation costs are also considered the savings become even more important.

Plastic pipe production offers the additional advantage of comparatively low-cost capital investment and low operation costs which make it feasible to install plants at strategic points to supply the needs of regions as a whole. Market studies could determine the logical locations for these plants. The need for standardization and of quality control becomes all the more important to assure that plastic pipe, which can be made to meet the needs of potable water supply service, is actually produced.

The population figures in the following table and the numbers of people served are estimated for the years indicated at the top of the tabulation. To get the true picture, consideration must be given to population increases

TABLE 18

ESTIMATED AVAILABILITY OF WATER SERVICE
(All population number figures in millions)

Area	Northern Africa*		Southern Africa*		East Asia**		Latin America***		Near East and South Asia**	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Total Population	58.5	100	234.5	100	243.4	100	254.3	100	687.3	100
Urban Population	19.1	33	27.4	12	56.2	23	135.8	53	131.5	19
Served	14.7	77	14.0	51	24.3	43	95.3	70	61.4	47
Not Served	4.4	23	13.4	49	31.9	57	40.5	30	70.1	53
Rural Population	39.4	67	207.1	88	187.1	77	118.5	47	555.8	81
Served	11.8	30	55.9	27	-	25?	19.1	16	50. ?	<10?
Not Served	27.6	70	151.2	73	-	75?	99.4	84	500. ?	>90?
Total Population Served	26.5	45	69.1	30	70?	30?	114.4	45	120.	<20
Total Population Not Served	32.0	55	164.6	70	170?	70?	139.9	55	560.	>80

Source: McJunkin, F.E. "Community Water Supply In Developing Countries." AID, Washington, 1969.

*1964 **1962 ***1967

which are highest, percentage wise, in these same developing areas of the world. The United Nations estimates that the world population will reach 7.4 billion by 2000, and increase of 4.1 billion over the 3.3 estimated in 1965. Over 85 percent of the increase will be in the high-birth-rate developing countries of Asia, Africa and Latin America. So that it is not only a question of improving present inadequate services and catching up in providing services for people not now served, but also of providing for the billions who are being added to existing population.

Tremendous strides have been made in Latin America since the start of the Alliance for Progress Decade in 1961 and progress in providing water supply services is keeping ahead of population increase. In 1961 60 percent of the urban population had water supply service by house connections or public hydrants. By the end of 1969 72 percent of the urban population was being served. The rural population with water supply services increased from 7 percent to 16 percent during the same period.

Dollar Volume

The Latin American progress was possible because of the existence of a cadre of well-trained sanitary engineers, officials who were and are convinced of the need for potable water facilities, and the willingness of government and international lending agencies to make funds available for these facilities. From 1961 through 1969 it is estimated that nearly 1.7 billion dollars have been allocated for water supply and sewerage facilities in Latin America, 37.5 percent of the money ($637 million) coming from international agencies.

Unfortunately international sources have not provided this amount of assistance for other areas of the world where it is so desperately needed. Total worldwide international capital assistance for water supplies has been about one billion dollars. However, a change in attitude by international lenders may be underway.

A recent conference on international development agreed that a "marked change in emphasis was essential for future development." In the past policy recommendations have focussed almost exclusively on enlarging the flow of goods and services. Little attention has been paid to who was receiving them. Now there is a new recognition that even enlarged output may have little effect on the lives of the landless laborers in Bihar or slum dwellers in Calcutta. The new style calls for "social growth" programs to promote employment, provide clean water and sanitary drains to the bustees of Calcutta, more schooling, a more equal distribution of the gains from expanded output.

The president of the World Bank publicly made the new style official policy for the lending institutions over which he presides. He suggested that loans would flow more freely to "nations building local irrigation works rather than large dams, schools instead of steel mills."

This new style policy could be instrumental in making more money available for water supply construction in the areas where it is so urgently needed.

In 1967 the countries of Latin America, with PAHO assistance, developed projections of the amounts of money they would allocate during the period 1968 through 1971 for water supply and sewerage construction to provide new or improved services. Their projections are shown in Table 19.

The second part of the table has been developed to ascertain what might be involved if other areas of the world could increase the numbers of people served in urban and rural areas by the same percentage as the Latin American area plans during the four-year period 1968-71. Approximately 200 million more people would be served at a cost of nearly U.S.$5-6 billion. Purchases of pipe could be as much as 25 percent of all expenditures.

While this may not be possible during the same four-year period, it will be possible over a longer period of time. It gives some idea of the possibilities for water supply construction in the developing world and of possible markets for plastic pipe and plastic pipe production in those areas.

While this document is primarily concerned with production and use of plastic pipe for water supply, sewerage systems, and related uses, it should be borne in mind that a plastic plant can be used to manufacture other types of

TABLE 19
FOUR YEAR PROJECTIONS 1968-1971

WATER SUPPLY IN LATIN AMERICA

	URBAN			RURAL		
Population and Costs in Millions	Add. People to be Served	% 1967 Pop. Served	Est. Cost	Add. People to be Served	% 1967 Pop. Served	Est. Cost
LATIN AMERICA	34.7	45	$1348	10.5	55	$ 226
SIMILAR INCREASE IN SERVICES IN OTHER AREAS						
AFRICA - NORTH	6.6	45	$ 256	6.5	55	$ 140
SOUTH	6.2	45	$ 241	30.8	55	$ 662
EAST ASIA	11.0	45	$ 427	25.9	55	$ 557
NEAR EAST AND SOUTH ASIA	27.6	45	$1073	27.5	55	$ 592
TOTALS	51.4		$1997	90.7		$1951
GRAND TOTAL						$5522

products. Any market study carried out to determine the feasibility of establishing a plastic plant should consider the market for other possible products as well. A plant for manufacturing pipe fittings could easily adapt to production of sandals, for example.

Role of U.S. Industry

The U.S. plastic pipe industry has five principal opportunities in promoting plastic pipe in the developing countries: (1) sale of pipe, (2) sale of fittings, (3) sale of plastic resins and compounds, (4) sale of machinery and molds, and (5) provision of capital and/or technical assistance.

Sale of Pipe

The potential market for sale of pipe is limited by shipping costs, local competition (plastic and non-plastic pipe), and third-country competition.

To ship small diameter pipe (4-inch or less) to the Caribbean costs 4¢/lb. For larger diameters, a rule of thumb is to add 1¢/lb. per inch in diameter. To ship 18-inch pipes to Asia costs about 30¢/lb., more than the cost of the pipe itself. Large resin shipments, on the other hand, can be negotiated at commodity rates; e.g., resin shipments have gone to New Zealand at 3¢/lb.

Shipping costs would seem to limit sale of U.S. manufactured pipes to the Western hemisphere. However, plastic pipe is manufactured locally, often by U.S. owned or affiliated firms in Mexico, Honduras, El Salvador, Nicaragua, Costa Rica, Panama, Puerto Rico, Jamaica, Columbia, Peru, Brazil, and possibly others. A thorough search of Commerce Department data failed to disclose any significant U.S. plastic pipe exports. This is not a promising long-run market.

Sale of Fittings

The difficulty and expense (see previous section on "Manufacture of Plastic Pipe") of producing quality fittings make this a potential specialty market. The higher unit sales prices somewhat negate shipping costs. All three major U.S. fittings and mold producers are active internationally. The metric barrier is a major obstacle to these firms.

Sale of Plastic Resins and Compounds

Several major U.S. producers are active in Latin America both in sale of U.S. produced resins and in Mexico, their manufacture as well. One U.S. firm produces resins in Iran and in India.

This is a promising market: (1) economics of scale and high fixed costs limit basic production plants to the major countries and, except for Japan and Europe, those with oil resources, (2) capital-intensive characteristics of production, automation, and proximity to petrochemicals, enable the U.S. to compete in the world market, (3) all U.S. producers maintain large, active marketing staffs, (4) the U.S. tradition of customer assistance, and (5) the relatively small investment required for an extrusion plant will result in growing demand.

One manufacturer of both resins and pipe sums up the prospects thusly:

"... I am certain that this is a sharply growing market, as the supply of water to households and its disposal once used is possibly the most acute need that one can observe in the developing countries. To what heights it can go it is difficult to speculate.

We are contemplating establishment of our own wholly owned subsidiaries. I feel it more logical, in the long term, to export knowhow rather than pipe for it is part of the pipe makers art that he sell the maximum of fresh air surrounded by a minimum of material and this makes for exceedingly heavy shipping costs!

Normally we do not export the raw materials for the use of others in extruding plastic pipes but it might be that in overseas plants we would be in a position to feed them with correctly mixed and formulated raw materials so that such export might commence based upon overseas plants."

The one area that is perhaps being overlooked is Africa, south of the Sahara. Except for exports of plastics materials to South Africa, there is little plastic pipe production or use. Nigeria, with the largest population on the continent, has an active water supply program, an oil refinery, and is receptive to foreign investment. Other likely candidates for plastic pipe production might be the Congo (Kinshasha), Ghana, and the East African Community (Uganda, Kenya, and Tanzania). These countries are virtually as close by sea to New York as to London.

Sale of Machinery

At least two U.S. firms have made sales in Latin America. Nearly all developing countries will of necessity be importing their extruders, injection molders, molds, etc. for many years to come. Joint efforts with major resin producers would appear to be mutually beneficial.

Provision of Capital and Know-How

The American business tradition of providing capital and technical assistance to its customers is definitely a promotional strongpoint in this industry.

Overseas Business Assistance

Both the U.S. Department of Commerce and the Agency for International Development conduct a number of programs and provide a number of services to assist U.S. businesses abroad. These are detailed in Appendix E. Information sources, financial assistance, and investment guaranties are among the topics covered.

APPENDIX A

ABBREVIATIONS

ABS	acrylonitrile-butadiene-styrene plastics
A.C., A.C.P.	asbestos cement, asbestos cement pipe
A.G.A.	American Gas Association
AID	Agency for International Development
ASCE	American Society for Civil Engineers
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
BSI	British Standards Institution
C.I., C.I.P.	cast iron, cast iron pipe
CS	Commercial Standard, see Product Standard
DWV	drainage, waste, and vent (pipe)
FHA	Federal Housing Administration or, Farmers Home Administration
HDS	hydrostatic design stress
ID	inside diameter
ISO	International Standards Organization
KIWA	Institution for the Testing of Waterworks Materials, Ltd. (Dutch)
NSF	National Sanitation Foundation
OD	outside diameter
PAHO	Pan American Health Organization
PE	polyethylene plastic or resin
PPI	Plastics Pipe Institute
PS	polystyrene when in reference to a plastic material
PS	Product Standard when in reference to a specification for plastic pipe and fittings. These specifications are promulgated by the U.S. Department of Commerce and were formerly known as Commercial Standards.
PSI	pounds per square inch
PSIG	gage pressure in pounds per square inch
PVC	poly (vinyl chloride) plastic or resin
RHDS	recommended hydrostatic design stress

SCS	Soil Conservation Service
SDR	standard dimension ratio
SPI	The Society of the Plastics Industry, Inc.
SR	styrene-rubber plastic
uPVC	unplasticized PVC
USASI	United States of America Standards Institute (formerly American Standards Association)
USPHS	U.S. Public Health Service
WHO	World Health Organization

APPENDIX B

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APPENDIX C

STANDARDS AND SPECIFICATIONS FOR PLASTIC PIPE

United States

ANSI	American National Standards Institute, Inc. (See USASI).
ASTM	American Society for Testing and Materials 1916 Race Street Philiadelphia, Pennsylvania 19103
D 702-64T	Cast Methacrylate Plastic Sheets, Rods, Tubes and Shapes
D 709-66T	Laminated Thermosetting Materials
D 1180-57(1961)	Test for Bursting Strength of Round Rigid Plastic Tubing
D 1238-65T	Measuring Flow Rates of Thermoplastics by Extrusion Plastometer
D 1248-69	Polyethylene Molding and Extrusion Materials
D 1503-68	Cellulose Acetate Butyrate (CAB) Plastic Pipe, Schedule 40
D 1527-69	Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe, Schedule 40 and 80
D 1598-67	Time-to-Failure of Plastic Pipe Under Long-Term Hydrostatic Pressure
D 1599-69	Short-Time Rupture Strength of Plastic Pipe, Tubing and Fittings
D 1694-67	Threads for Reinforced Thermosetting Plastic Pipe
D 1784-68	Polyvinyl Chloride (PVC) Compounds and Chlorinated Polyvinyl Chloride (CPVC) Compounds, Rigid
D 1785-68	Poly(Vinyl Chloride)(PVC) Plastic Pipe, Schedules 40, 80, and 120
D 1788-68	Rigid Acrylonitrile-Butadiene-Styrene (ABS) Plastics
D 1939-67	Quality of Extruded Acrylonitrile-Butadiene-Styrene (ABS) Pipe by Acetic Acid Immersion
D 2104-68	Polyethylene (PE) Plastic Pipe, Schedule 40

D 2105-67	Longitudinal Tensile Properties of Reinforced Thermosetting Plastic Pipe and Tube
D 2122-67	Determining Dimensions of Thermoplastic Pipe
D 2143-63T	Cyclic Pressure Strength of Reinforced, Thermosetting Plastic Pipe
D 2152-67	Quality of Extruded Poly(Vinyl Chloride) Pipe by Acetone Immersion
D 2153-67	Calculating Stress in Plastic Pipe Under Internal Pressure
D 2235-67	Solvent Cement for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe and Fittings
D 2239-67	Polyethylene (PE) Plastic Pipe (SDR-PR)
D 2241-67	Poly(Vinyl Chloride) (PVC) Plastic Pipe (SDR-PR and Class T)
D 2282-69a	Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (SDR-PR and Class T)
D 2290-64T	Apparent Tensile Strength of Parallel Reinforced Plastics by Split Disk Method
D 2310-64T	Reinforced Thermosetting Plastic Pipe
D 2321-67	Underground Installation of Flexible Thermoplastic Sewer Pipe
D 2412-68	External Loading Properties of Plastic Pipe by Parallel-Plate Loading
D 2444-67	Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)
D 2446-68	Cellulose Acetate Butyrate (CAB) Plastic Pipe (SDR-PR) and CAB Plastic Tubing
D 2447-68	Polyethylene (PE) Plastic Pipe, Schedules 40 and 80 Based on Outside Diameter
D 2464-67	Threaded Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
D 2465-68	Threaded Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe Fittings, Schedule 80
D 2466-67	Socket-Type Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40
D 2467-67	Socket-Type Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
D 2468-68	Socket-Type Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe Fittings, Schedule 40
D 2469-68	Socket-Type Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe Fittings, Schedule 80

ASTM *(Cont'd)*

D 2513-68	Thermoplastic Gas Pressure Pipe, Tubing, and Fittings
D 2517-67	Reinforced Thermosetting Plastic Gas Pressure Pipe and Fittings
D 2560-67	Solvent Cements for Cellulose Acetate Butyrate (CAB) Plastic Pipe and Fittings
D 2564-67	Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Pipe and Fittings
D 2581-67	Polybutylene(PB) Plastics
D 2609-68	Plastic Insert Fittings for Polyethylene (PE) Plastic Pipe
D 2610-68	Butt Fusion Polyethylene (PE) Plastic Pipe Fittings, Schedule 40
D 2611-68	Butt Fusion Polyethylene (PE) Plastic Pipe Fittings, Schedule 80
D 2657-57	Heat Joining of Thermoplastic Pipe and Fittings
D 2661-68	Acrylonitrile-Butadiene-Styrene (ABS) Plastic Drain, Waste, and Vent Pipe and Fittings
D 2662-68	Polybutylene (PB) Plastic Pipe (SDR-PR)
D 2665-68	Poly(Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings
D 2666-67T	Polybutylene (PB) Plastic Tubing
D 2672-68a	Bell End PVC Plastic Pipe
D 2680-68T	Acrylonitrile-Butadiene-Styrene (ABS) Composite Pipe
D 2683-68T	Socket Type Polyethylene (PE) Fittings for SDR 11.0 PE Pipe
D 2729-68	Polyvinyl Chloride (PVC) Sewer Pipe and Fittings
D 2736-69T	Filled-Polyvinyl Chloride (PVC) Sewer Pipe and Fittings
D 2737-68T	Polyethylene (PE) Plastic Tubing
D 2740-68	Polyvinyl Chloride (PVC) Plastic Tubing
D 2749-68	Standard Definitions of Terms Relating to Plastic Pipe Fittings
D 2750-69	Acrylonitrile-Butadiene-Styrene (ABS) Plastic Utilities Conduit and Fittings
D 2751-69	Acrylonitrile-Butadiene-Styrene (ABS) Sewer Pipe and Fittings
D 2774-69	Recommended Practice for Underground Installation of Thermoplastic Pressure Piping
D 2837-69	Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials

ASTM *(Cont'd)*

D 2846-69T	Chlorinated Polyvinyl Chloride (CPVC) Plastic Hot Water Distribution Systems
D 2852-69T	Styrene-Rubber (SR) Plastic Drain and Building Sewer Pipe and Fittings
D 2855-70	Making Solvent Cemented Joints with Polyvinyl Chloride (PVC) Pipe and Fittings
Commercial and Product Standards	Superintendent of Documents U.S. Government Printing Office Washington, D. C. 20402
PS10-69	Polyethylene (PE) Plastic Pipe (Schedule 40 Inside Diameter Dimensions), Supersedes CS197-60
PS11-69	Polyethylene (PE) Plastic Pipe (SDR), Supersedes CS255-63
PS12-69	Polyethylene (PE) Plastic Pipe (Schedule 40 and 80-Outside Diameter Dimensions)
PS18-69	Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (Schedules 40 and 80), Supersedes Cs218-59.
PS19-69	Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (Standard Dimension Ratio), Supersedes CS254-63
PS21-70	Polyvinyl Chloride (PVC) Plastic Pipe (Schedules 40, 80, and 120), Supersedes CS207-60
PS22-70	Polyvinyl Chloride (PVC) Plastic Pipe (Standard Dimension Ratio), Supersedes CS256-63
CS270-65	Acrylonitrile-Butadiene-Styrene (ABS) Plastic Drain, Waste and Vent Pipe and Fittings
CS272-65	Polyvinyl Chloride (PVC) Plastic Drain, Waste and Vent Pipe and Fittings
Department of Agriculture	U.S. Department of Agriculture Soil Conservation Service Washington, D.C. 20250

SDS National Engineering Handbook, Section 2, Part 1, Engineering Practice Standards

No. 432-D	High Pressure Underground Plastic Irrigation Pipelines (February 1967)
No. 432-E	Low Head Underground Plastic Irrigation Pipelines (February 1967 with amendment of June 14, 1967)
Department of Defense Military Standards	Commanding Officer Naval Publications and Form Center 5801 Tabor Avenue Philadelphia, Pennsylvania 19120
MIL-C-23571a	Conduit and Conduit Fittings, Plastic, Rigid (11-8-68)
MIL-A-22010A(1)	Adhesive, Solvent-type, Polyvinyl Chloride (6-9-61)

Department of Defense Military Standards *(Cont'd)*

MIL-P-5431A(1)	Plastic, Phenolic, Graphited, Sheets, Rods, Tubes and Shapes (2-29-68)
MIL-P-14529A	Pipe, Extruded, Thermoplastic (12-18-62)
MIL-P-19119B(1)	Pipe, Plastic, Rigid, Unplasticized, High Impact, Polyvinyl Chloride (6-28-65)
MIL-P-22011A	Pipe Fittings, Plastic, Rigid, High Impact, Polyvinyl Chloride (PVC) and Poly 1, 2 Dichlorethylene (1-13-69)
MIL-P-21922A	Plastic Rods and Tubes, Polyethylene (7-11-66)
MIL-P-22245A(1)	Pipe and Pipe Fittings, Polyethylene, for Low-pressure Waste and Drainage Systems (2-11-66)
MIL-P-26692	Plastic Tubes and Tubing, Polyethylene
MIL-P-82056	Pipe and Pipe Fittings, Plastic for Drain, Waste and Vent Service (1-29-68)
Federal Specifications	Specifications Activity Printed Materials Supply Division Building 197 Naval Weapons Plant Washington, D.C. 20407
L-P-00315b	Pipe, Plastic (Polyethylene, PE, SDR-PR) (12-7-67)
L-P-320a	Pipe and Fittings, Plastic (PVC, Drain, Waste and Vent) (11-25-66)
L-P-322a	Pipe and Fittings, Plastic (ABS, Drain, Waste and Vent) (1-12-66)
L-P-1036(1)	Plastic Rod, Solid; Plastic Tubes and Tubing, Heavy Walled; Polyvinyl Chloride, Rigid (6-26-67) Amendment 1 (1-29-68)
L-T-00790	Tubing, Thermoplastic (Laboratory and Medical) (6-30-61)
L-P-001221	Pipe and Fittings, Plastic, Rigid (Styrene Rubber, Drain and Sewer) (3-1-67)
FHA	Architectural Standards Division Federal Housing Administration Washington, D.C.

FHA Minimum Property Standards Interim Revision No. 31 (June, 1966)

FHA UM-26b	Plastic Drain and Sewer Pipe and Fittings (5-15-67)
FHA UM-31e	Polyethylene Plastic Pipe and Fittings for Domestic Water Service (9-1-66)
FHA UM-41	PVC Plastic Pipe and Fittings for Domestic Water Service (8-1-66)
FHA UM-43	Acrylonitrile-Butadiene-Styrene Plastic Pipe and Fittings for Domestic Water Service (11-1-66)

FHA *(Cont'd)*

FHA UM-49	ABS and PVC Plastic Drainage and Vent Pipe and Fittings, FHA 4550.49 (5-1-68)
FHA MR-562	Rigid Chlorinated Polyvinyl Chloride (CPVC) Hi-Temp. Water Pipe and Fittings (11-3-67)
FHA MR-563	PVC Plastic Drainage and Vent Pipe and Fittings (11-6-67)
IAPMO	International Association of Plumbing and Mechanical Officials (formerly WOPA) 5032 Alhambra Street Los Angeles, California 90032
IAPMO (WPOA) TSC 6-61	Plastic Drain and Vent Pipe–Drainage Fittings for Trailer Coach Drainage and Vent Systems ABS - Type 1 and 1A
IAPMO (WPOA) PS 17-66	Materials and Property Standards for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Drain, Waste and Vent Pipe and Fittings
IAPMO (WPOA) IS 5-66	Installation Standard for ABS Drain, Waste and Vent Pipe and Fittings
IAPMO IS 8-67	Installation Standard for Solvent Cemented PVC Pipe for Water Service and Yard Piping
IAPMO IS10-69T	Installation Standard for Thermoplastic Yard Gas Piping
IAPMO PS30-69T	Supplemental Standard to ABS Sewer Pipe and Fittings Standard ASTM D2751
IAPMO IS11-69T	Installation Standard for ABS Sewer Pipe and Fittings
IAPMO 19-68	Installation Standard for PVC Drain, Waste and Vent Pipe and Fittings
NSF	National Sanitation Foundation School of Public Health University of Michigan Ann Arbor, Michigan
NSF Standard No. 14:	Thermoplastic Materials, Pipe, Fittings, Valves, Traps and Joining Materials (October 1965)
NSF Standard No. 15:	Thermoset Plastic Pipe, Fittings, Valves, Tanks, Appurtenances, Joining Materials and Thermoset Plastic Coatings for Use in Potable Water Systems

NSF Seal of Approval Listing of Plastic Materials, Pipe, Fittings and appurtenances for Potable Water and Waste Water (NSF Testing Laboratory) (3-1-69)

PPI	Plastics Pipe Institute 250 Park Avenue New York, New York 10017

PPI *(Cont'd)*

	See bibliography in Appendix B for several recommended practices and procedures.
SIA	Sprinkler Irrigation Association 1028 Connecticut Avenue, N.W., Washington, D.C. 20036

Minimum Standards for Irrigation Equipment (March 1959)

UL	Underwriters Laboratories, Inc. 207 East Ohio Street Chicago, Illinois 60611
UL 651	Rigid Nonmetallic Conduit (September 1968)
UL 514	Outlet Boxes and Fittings (March 1951-with amendments of 2-28-67)
USASI	United States of America Standards Institute 10 East 40th Street New York, N.Y. 10016
	Note: Effective October 6, 1969, the USASI changes its name to American National Standards Institute, Inc., and its address to 1430 Broadway, New York, N.Y. 10018. "USA Standards" will then become "American National Standards." USASI was the successor (1966) of the American Standards Association (ASA).
USAS A119.2-1963	Plumbing, Heating and Electrical Systems for Travel Trailers
USAS B16.27-1962	Plastic Insert Fittings for Flexible Polyethylene Pipe
USAS B72.1-1967	Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) (ASTM D2239-67)
USAS B72.2-1967	Specification for Polyvinyl Chloride (PVC) Plastic Pipe (SDR-PR) ASTM D2241-67)
USAS B72.3-1967)	Specification for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (SDR-PR and Class T) ASTM D2282-66)
USAS B31.8-1968	USA Standard Code for Pressure Piping, Gas Transmission and Distribution Piping Systems
USAS C59.40-1967	Polyethylene Molding and Extrusion Materials

Foreign

(Partial Listing)

International

ISO	*International Organization for Standardization ISO Central Secretariat 1, Rue de Varembe 1211 Geneva 20, SWITZERLAND

*ISO Recommendations are available in English, French, and Russian. Copies may be obtained through the member bodies (USASI for the U.S.).

ISO *(Cont'd)*

R 161-1960	Pipes of Plastics Materials for the Transport of Fluids (Outside Diameters and Nominal Pressures). Part I: Metric Series
R 264-1962	Pipes and Fittings of Plastics Materials. Socket Fittings for Pipes Under Pressure. Basic Dimensions. Metric Series
R 265-1962	Pipes and Fittings of Plastics Materials. Socket Fittings with Spigot Ends for Domestic and Industrial Waste Pipes, Basic Dimensions. Metric Series
R 330-1963	Pipes of Plastics Materials for the Transport of Fluids (Outside Diameters and Nominal Pressures). Part II: Inch Series
R 580-1967	Oven Test for Moulded Fittings in Unplasticized Polyvinyl Chloride (PVC) for Use Under Pressure.
R 727-1968	Socket Fittings for Pipes Under Pressure. Unplasticized PVC Fittings with Plain Sockets. Metric Series
**DR 1330	Plastics Pipes for the Transport of Fluids. Unplasticized Polyvinyl Chloride Pipes. Tolerance on Outside Diameters.
**DR 1331	Plastics Pipes for the Transport of Fluids. Polyethylene Pipes. Tolerance on Outside Diameters.
**DR 1332	Plastics Pipes for the Transport of Fluids. Unplasticized Polyvinyl Chloride Pipes. Tolerances on Wall Thicknesses up to 6mm.
**DR 1333	Plastics Pipes for the Transport of Fluids. Polyethlene Pipes. Tolerances on Wall Thicknesses up to 6 mm.
**DR 1334	Plastics Pipes for the Transport of Fluids. Determination of the Burst Strength.

Israel

S.I.	The Standards Institute of Israel University Street Ramat Aviv Tel Aviv, Israel
S.I. No. 498-1963	Flexible Polyvinyl Chloride Pipe
S.I. No. 499-1963	Low Density Polythene Pipe
S.I. No. 532-1964	Hard Polyvinyl Chloride Pipe for Drinking Water
S.I. No. 576-1965	Hard Polyvinyl Chloride Pipe for Domestic Waste and Sewage Water
S.I. No. 645-1967	Hard Polyvinyl Chloride Fittings for Pipes Carrying Drinking Water

**DR - Abbreviation for "Draft Recommendation"

Japan

JIS	Japanese Industrial Standards Committee
	(English translations available from Japanese Standards Association, 89, Hitotsugi-cho, Akasaka, Minato-ku Tokyo, Japan.)
JIS K 6700-1958	Celluloid Pipe for Water Works Service
JIS K 6741-1965	Rigid Polyvinyl Chloride Pipes
JIS K 6742-1964	Rigid Polyvinyl Chloride Pipes for Water Works Service
JIS K 6762-1966	Polyethylene Pipes for Water Works Service
JIS K 6763-1965	Polyethylene Pipe Fittings for Water Works Service

Mexico

DGN	Direccion General de Normas Av. Cuauhtemac No. 80 Mexico 7, D.F. Mexico
DGN-K-144-1967	Norma Official para Tubos y Connexiones de Policluro de Vinilo.
	Also see Institute de Ingeniera, UNAM, in the Bibliography (Appendix B).

Netherlands

KIWA	Keuringsinstituut Voor Waterleidingartikelen (KIWA) Institution for the Testing of Waterworks Materials, Ltd. (KIWA) Sir Winston Churchill-laan 273 The Hague, The Netherlands
KIWA	Test Specifications: Water Pipes Made of Hard Polyvinyl Chloride with Outside Diameters from 50 up to and Including 400 mm. 1962.

United Kingdom

BS	British Standards Institution British Standards House 2 Park Street London, W1 England
BS 1972:1967 (Amended)	Polythene Pipe (Type 32) for Cold Water Services
BS 3284:1967	Polythene Pipe (Type 50) for Cold Water Services
BS 3505:1968	Unplasticized PVC Pipe (Type 1420) for Cold Water Supply
BS 3506:1962	Unplasticized PVC Pipe for Industrial Use
BS 3867:1965	Dimensions of Pipes of Plastics Materials (Outside Diameters)

BS *(Cont'd)*

BS 4159:1967	Colour Marking of Plastics Pipes to Indicate Pressure Ratings

West Germany

DIN	Deutscher Normenausschuss English translations available from Beuth-Vertrieb Gmbtt 1 Berlin 30 West Germany
DIN 8061	Tubes of Pipes of Rigid PVC (Rigid Polyvinyl Chloride); Technical Conditions of Delivery
DIN 8062	Tubes of Pipes of Rigid PVC (Rigid Polyvinyl Chloride); Dimensions
DIN 8072	Tube and Piping of Flexible PE (Polyethylene); Dimensions
DIN 8074	Tube and Piping of Rigid PE (Polyethylene); Dimensions
DIN 16933	Tube and Piping of PE (Polyethylene); Directions for Use

Others

Other countries with standards or semi-official rules or both include Austria, Belgium, Czechoslovakia, Denmark, France, Hungary, Ireland, Norway, Pakistan, Peru, Poland, South Africa, Sweden, and the Soviet Union.

Some countries publish no local standards but use ISO Recommendations (note that these cover only dimensions and working pressures). The Indian Standards Institute, for example, lists ISO Recommendations 161, 264, and 330 as its standards for plastic pipe. Some importing countries use the standards of those countries supplying the pipe, principally the U.S., Britain, and Japan. Note that the latter two allow use of lead stabilizers.

APPENDIX D

A GLOSSARY OF PLASTICS PIPING TERMS

Foreword

Plastics piping has its own technical vocabulary, much of which is new to the water works industry and to some readers of this report. This appendix is intended to provide a working vocabulary for those public officials and engineers with new responsibilities or interest in use of plastics pipe and for those who seek to improve their knowledge through further study of the voluminous literature (see Appendix B) of the subject or communication with the plastics industry.

The majority of these definitions are extracted from publications of the American Society for Testing Materials (ASTM), Plastics Pipe Institute, and the *Handbook of Reinforced Plastics of the Society of the Plastics Industry.*

Nomenclature

ABS truss pipe - pipe that derives its name from its cross-sectional configuration of concentric inner and outer walls of ABS connected in truss-like fashion by webs of the same material with lightweight concrete filling the intervening spaces to maintain the truss shape. See acrylonitrile-butadiene-styrene (ABS) pipe.

Acceptance test - an investigation performed on an individual lot of a previously qualified product, by, or under the observation of, the purchaser to establish conformity with a purchase agreement.

Acrylonitrile-butadiene-styrene (ABS) pipe and fitting plastics - plastics containing polymers and/or blends of polymers, in which the minimum butadiene content is 6 percent, the minimum acrylonitrile content is 15 percent, the minimum styrene and/or substituted styrene content is 15 percent, and the maximum content of all other monomers is not more than 5 percent, and lubricants, stabilizers and colorants.

Aging, n.- (1) The effect on materials of exposure to an environment for an interval of time.

(2) The process of exposing materials to an environment for an interval of time.

Antioxidant - a compounding ingredient added to a plastic composition to retard possible degradation from contact with oxygen (air), particularly in processing at or exposures to high temperatures.

Bell end - the enlarged portion of a pipe that resembles the socket portion of a fitting and that is intended to be used to make a joint by inserting a piece of pipe into it. Joining may be accomplished by solvent cements, adhesives, or mechanical techniques.

Burst strength - the internal pressure required to break a pipe or fitting. This pressure will vary with the rate of build-up of the pressure and the time during which the pressure is held. See burst strength, fiber stress, hoop stress, hydrostatic design stress, long-term hydrostatic strength, hydrostatic strength (quick), long-term burst, ISO equation, pressure, pressure rating, quick burst, service factor, strength, stress, and sustained pressure test are related terms.

Cement - See adhesive and solvents, cement.

Chemical resistance - (1) the effect of specific chemicals on the properties of plastic piping with respect to concentration, temperature and time of exposure.

- (2) the ability of a specific plastic pipe to render service for a useful period in the transport of a specific chemical at a specified concentration and temperature.

Cold flow - See Creep.

Compound - the intimate admixture of a polymer or polymers with other ingredients such as fillers, softeners, plasticizers, catalysts, pigments, dyes, curing agents, stabilizers, antioxidants, etc.

Creep, n.- the time-dependent part of strain resulting from stress, that is, the dimensional change caused by the application of load over and above the elastic deformation and with respect to time.

Cure, v.- to change the properties of a polymeric system into a final, more stable, usable condition by the use of heat, radiation, or reaction with chemical additives.

Deflection temperature - the temperature at which a specimen will deflect a given distance at a given load under prescribed conditions of test. See ASTM D648. Formerly called heat distortion.

Degradation, n.- a deleterious change in the chemical structure of a plastic. See also Deterioration.

Deterioration - a permanent change in the physical properties of a plastic evidenced by impairment of these properties.

Dimension ratio - the diameter of a pipe divided by the wall thickness. Each pipe can have two dimension ratios depending on whether the outside or inside diameter is used. In practice, the outside diameter is used if the standards requirement and manufacturing control are based on this diameter. The inside diameter is used when this measurement is the controlling one.

Elasticity - that property of plastics materials by virtue of which they tend to recover their original size and shape after deformation.

Note - If the strain is proportional to the applied stress, the material is said to exhibit Hookean or ideal elasticity.

Elastomer - a material which at room temperature can be stretched repeatedly to at least twice its original length and, upon immediate release of the stress, will return with force to its approximate original length.

Elevated temperature testing - tests on plastic pipe above 23C (73F).

Environmental stress cracking - cracks that develop when the material is subjected to stress in the presence of specific chemicals.

Extrusion - a method whereby heated or unheated plastic forced through a shaping orifice becomes one continuously formed piece.

Fiber stress - the unit stress, usually in pounds per square inch (psi), in a piece of material that is subjected to an external load.

Filler - a relatively inert material added to a plastic to modify its strength, permanence, working properties, or other qualities, or to lower costs. See also Reinforced Plastic.

Fungi resistance - the ability of plastic pipe to withstand fungi growth and/or their metabolic products under normal conditions of service or laboratory tests simulating such conditions.

Heat joining - making a pipe joint by heating the edges of the parts to be joined so that they fuse and become essentially one piece with or without the addition of additional material.

Hoop stress - the tensile stress, usually in pounds per square inch (psi), in the circumferential orientation in the wall of the pipe when the pipe contains a gas or liquid under pressure.

Hydrostatic design stress - the estimated maximum tensile stress in the wall of the pipe in the circumferential orientation due to internal hydrostatic pressure that can be applied continuously with a high degree of certainty that failure of the pipe will not occur.

Hydrostatic strength (quick) - the hoop stress calculated by means of the ISO equation at which the pipe breaks due to an internal pressure build-up, usually within 60 to 90 seconds.

Long-term burst - the internal pressure at which a pipe or fitting will break due to a constant internal pressure held for 100,000 hours (11.43 years).

Impact, Izod - a specific type of impact test made with a pendulum type machine. The specimens are molded or extruded with a machined notch in the center. **See** ASTM D256

Impact, Tup - a falling weight (tup) impact test developed specifically for pipe and fittings. There are several variables that can be selected. See ASTM D2444.

ISO equation - an equation showing the interrelations between stress, pressure and dimensions in pipe, namely

$$S = \frac{P\,(ID + t)}{2t} \text{ or } \frac{P\,(OD - t)}{2t}$$

where S = stress
P = pressure
ID = average inside diameter
OD = average outside diameter
t = minimum wall thickness

Reference: ISO R161-1960 Pipes of Plastics Materials for the Transport of Fluids (Outside Diameters and Nominal Pressures) Part I, Metric Series.

Joint - the location at which two pieces of pipe or a pipe and a fitting are connected together. The joint may be made by an adhesive, a solvent-cement or a mechanical device such as threads or a ring seal.

Long-term hydrostatic strength - the estimated tensile stress in the wall of the pipe in the circumferential orientation (hoop stress) that when applied continuously will cause failure of the pipe at 100,000 hours (11.43 years). These strengths are usually obtained by extrapolation of log-log regression equations or plots.

Molding, compression - a method of forming objects from plastics by placing the material in a confining mold cavity and applying pressure and usually heat.

Molding, injection - a method of forming plastic objects from granular or powdered plastics by the fusing of plastic in a chamber with heat and pressure and then forcing part of the mass into a cooler chamber where it solidifies.

Note - This method is commonly used to form objects from thermoplastics.

Monomer - a relatively simple chemical which can react to form a polymer. See also Polymer.

Nonrigid plastic - a plastic which has a stiffness or apparent modulus of elasticity of not over 10,000 psi at 23°C, when determined in accordance with the Standard Method of Test for Stiffness in Flexure of Plastics (ASTM Designation: D 747).

Olefin plastics - plastics based on resins made by the polymerization of olefins or copolymerization of olefins with other unsaturated compounds, the olefins being in greatest amount by weight. Polyethylene, polypropylene and polybutylene are the most common olefin plastics encountered in pipe.

Outdoor exposure - plastic pipe placed in service or stored so that it is not protected from the elements of normal weather conditions, i.e., the sun's rays, rain, air and wind. Exposure to industrial and waste gases, chemicals, engine exhausts, etc. are not considered normal "outdoor exposure."

Permanence - the property of a plastic which describes its resistance to appreciable changes in characteristics with time and environment.

Plastic, n.- a material that contains as an essential ingredient an organic substance of large molecular weight, is solid in its finished state, and, at some stage in its manufacture or in its processing into finished articles, can be shaped by flow.

Plastic, adj. - the adjective indicates that the noun modified is made of, consists of, or pertains to plastic.

Note 1 - The above definition may be used as a separate meaning to the definitions contained in the dictionary for the adjective "plastic."

Note 2 - The plural form may be used to refer to two or more plastic materials, for example, plastics industry. However, when the intent is to distinguish "plastic products" from "wood products" or "glass products," the singular form should be used. As a general rule, if the adjective is to restrict the noun modified with respect to type of material, "plastic" should be used; if the adjective is to indicate that more than one type of plastic material is or may be involved, "plastics" is permissible.

Plastic, rigid - a plastic which has a stiffness or apparent modulus of elasticity greater than 100,000 psi at 23°C, when determined in accordance with the Standard Method of Test for Stiffness in Flexure of Plastics (ASTM Designation: D 747).

Plastic, semirigid - a plastic which has a stiffness or apparent modulus of elasticity of between 10,000 and 100,000 psi at 23°C, when determined in accordance with the Standard Method of Test for Stiffness in Flexure of Plastics (ASTM Designation: D 747).

Plasticizer - a material incorporated in a plastic to increase its workability and its flexibility or distensibility.

Note - The addition of the plasticizer may lower the melt viscosity, the temperature of the second-order transition, or the elastic modulus of the plastic.

Plastics conduit - plastic pipe or tubing used as an enclosure for electrical wiring.

Plastic pipe - a hollow cylinder of a plastic material in which the wall thicknesses are usually small when compared to the diameter and in which the inside and outside walls are essentially concentric. See plastics tubing.

Plastics tubing - a particular size of plastics pipe in which the outside diameter is essentially the same as that of copper tubing. See plastics pipe.

Polyethylene, n.- a polymer prepared by the polymerization of ethylene as the sole monomer. See Polyethylene Plastics and Ethylene Plastics.

Polyethylene plastics - plastics based on polymers made with ethylene as essentially the sole monomer. Note: In common usage for this plastic, essentially means no less than 85% ethylene and no less than 95% total olefins.

Polymer - a compound formed by the reaction of simple molecules having functional groups that permit their combination to proceed to high molecular weights under suitable conditions. Polymers may be formed by polymerization (addition polymer) or polycondensation (condensation polymer). When two or more monomers are involved, the product is called a copolymer.

Polymerization - a chemical reaction in which the molecules of a monomer are linked together to form large molecules whose molecular weight is a multiple of that of the original substance. When two or more monomers are involved, the process is called copolymerization or heteropolymerization.

Poly (vinyl chloride) - a resin prepared by the polymerization of vinyl chloride with or without the addition of small amounts of other monomers.

Poly (vinyl chloride) plastics - plastics made by combining poly (vinyl chloride) with colorants, fillers, plasticizers, stabilizers, lubricants, other polymers, and other compounding ingredients. Not all of these modifiers are used in pipe compounds.

Pressure - when expressed with reference to pipe the force per unit area exerted by the medium in the pipe.

Pressure rating - the estimated maximum pressure that the medium in the pipe can exert continuously with a high degree of certainty that failure of the pipe will not occur.

Qualification test - an investigation, independent of a procurement action, performed on a product to determine whether or not the product conforms to all requirements of the applicable specification.

Note - The examination is usually conducted by the agency responsible for the specification, the purchaser, or by a facility approved by the purchaser, at the request of the supplier seeking inclusion of his product on a qualified products list.

Quick burst - the internal pressure required to burst a pipe or fitting due to an internal pressure build-up, usually within 60 to 90 seconds.

Reinforced plastic - a plastic with some strength properties greatly superior to those of the base resin, resulting from the presence of high strength fillers imbedded in the composition. See also Filler.

Resin - a solid, semisolid, or pseudosolid organic material which has an indefinite and often high molecular weight, exhibits a tendency to flow when subjected to stress, usually has a softening or melting range, and usually fractures conchoidally.

Reworked material (thermoplastic) - a plastic material that has been reprocessed, after having been previously processed by molding, extrusion, etc. in a fabricator's plant.

Rubber - a material that is capable of recovering from large deformations quickly and forcibly. See Elastomer.

Sample - a small part of portion of a plastic material or product intended to be representative of the whole.

Schedule - a pipe size system (outside diameters and wall thicknesses) originated by the iron pipe industry.

Self-extinguishing - the ability of a plastic to resist burning when the source of heat or flame that ignited it is removed.

Service factor - a factor which is used to reduce a strength value to obtain an engineering design stress. The factor may vary depending on the service conditions, the hazard, the length of service desired, and the properties of the pipe.

Softening range - the range of temperature in which a plastic changes from a rigid to a soft state.

Note - Actual values will depend on the method of test. Sometimes referred to as softening point.

Solvent cement - in the plastic piping field, a solvent adhesive that contains a solvent that dissolves or softens the surfaces being bonded so that the bonded assembly becomes essentially one piece of the same type of plastic.

Solvent cementing - making a pipe joint with a solvent cement. See Solvent cement.

Specimen - an individual piece or portion of a sample used to make a specific test. Specific tests usually require specimens of specific shape and dimensions.

Stabilizer - a compounding ingredient added to a plastic composition to retard possible degradation on exposure to high temperatures, particularly in processing. An antioxidant is a specific kind of stabilizer.

Standard dimension ratio - a selected series of numbers in which the dimension ratios are constants for all sizes of pipe for each standard dimension ratio and which are the USASI Preferred Number Series 10 modified by +1 or -1. If the outside diameter (OD) is used the modifier is +1. If the inside diameter (ID) is used the modifier is -1.

Some of the numbers are as follows:

USASI PREFERRED NUMBER SERIES 10	OD CONTROL	ID CONTROL
5.	6.	4.
6.3	7.3	5.3
8.	9.	7.
10.	11.	9.
12.5	13.5	11.5
16.	17.	15.
20.	21.	19.
25.	26.	24.
31.5	32.5	30.5
40.	41.	39.
50.	51.	49.
63.	64.	62.

Reference: USASI Preferred Numbers, Z17.1-1958, UDS 389.17.

Standard thermoplastic pipe materials designation code - a means for easily identifying a thermoplastic pipe material by means of three elements. The first element is the abbreviation for the chemical type of the plastic in accordance with ASTM D1600. The second is the type and grade (based on properties in accordance with the ASTM materials specification); in the case of ASTM specifications which have no types and grades or those in the cell structure system, two digit numbers are assigned by the PPI that are used in place of the larger numbers. The third is the recommended hydrostatic design stress (RHDS) for water at 23C (73F) in pounds per square inch divided by 100 and with decimals dropped, e.g. PVC 1120 indicates that the plastic is poly (vinyl chloride), Type 1 Grade 1 according to ASTM D1784 with a RHDS of 2000 psi for water at 73F. PE 3306 indicates that the plastic is polyethylene, Type III Grade 3 according to ASTM D1248 with a RHDS of 630 psi for water at 73F. PP 1208 is polypropylene, Class I-19509 in accordance with ASTM D2146 with a RHDS of 800 psi for water at 73F; the designation of PP12 for polypropylene Class I-19509 will be covered in the ASTM and Product Standards for polypropylene pipe when they are issued.

Stiffness factor - a physical property of plastic pipe that indicates the degree of flexibility of the pipe when subjected to external loads. See ASTM D2412.

Strain - the ratio of the amount of deformation to the length being deformed caused by the application of a load on a piece of material.

Strength - the stress required to break, rupture or cause a failure.

Stress - when expressed with reference to pipe the force per unit area in the wall of the pipe in the circumferential orientation due to internal hydrostatic pressure.

Stress-crack - external or internal cracks in a plastic caused by tensile stresses less than that of its short-time mechanical strength.

Note - The development of such cracks is frequently accelerated by the environment to which the plastic is exposed. The stresses which cause cracking may be present internally or externally or may be combinations of these stresses. The appearance of a network of fine cracks is called crazing.

Styrene plastics - plastics based on resins made by the polymerization of styrene or copolymerization of styrene with other unsaturated compounds, the styrene being in greatest amount by weight.

Styrene-rubber plastics - compositions based on rubbers and styrene plastics, the styrene plastics being in greatest amount by weight.

Styrene-rubber (SR) pipe and fitting plastics - plastics containing at least 50 percent styrene plastics combined with rubbers and other compounding materials, but not more than 15 percent acrylonitrile.

Thermoplastic, n.- a plastic which is thermoplastic in behavior.

Thermoplastic, adj. - capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature.

Note - Thermoplastic applies to those materials whose change upon heating is substantially physical.

Thermoset, n. - a plastic which, when cured by application of heat or chemical means, changes into a substantially infusible and insoluble product.

Thermoset, adj. - pertaining to the state of a resin in which it is relative infusible.

Thermosetting - capable of being changed into a substantially infusible or insoluble product when cured under application of heat or chemical means.

Vinyl Chloride plastics - plastics based on resins made by the polymerization of vinyl chloride or copolymerization of vinyl chloride with other unsaturated compounds, the vinyl chloride being in greatest amount by weight.

Virgin material - a plastic material in the form of pellets, granules, powder, floc, or liquid that has not been subjected to use or processing other than that required for its original manufacture.

APPENDIX E

OTHER INFORMATION SOURCES

General Information

The principal industry association is the Plastics Pipe Institute of the Society of the Plastics Industry, Inc. Its address is 250 Park Avenue, New York, N.Y. 10017. G.R. Munger is Executive Director. Dr. Frank W. Reinhart, 9918 Sutherland Road, Silver Spring, Md., serves as the Plastics Pipe Institute's Technical Director.

Testing Programs

Virtually all plastics pipe used in public water systems in the United States carries the "Seal of Approval" of the National Sanitation Foundation Testing Laboratory, Inc., Ann Arbor, Michigan, including imported pipe of foreign manufacture. The NSF has under consideration several proposals for extending their seal program to other countries. Somewhat similar programs are offered by British (BSI) and Dutch (KIWA) organizations.

Overseas Business Assistance

The U.S. Department of Commerce conducts a number of programs and provides extensive services which can be of material assistance to U.S. firms interested in expanding their operations through overseas investments, particularly in the less-developed countries.

In the main, these programs and services–which do not include, however, financial assistance or credit facilities–consist of:

The Office of International Investment, which has as a primary mission the promotion of U.S. investment abroad. Its staff is prepared to advise and assist U.S. firms contemplating overseas investment. It is in direct contact with all U.S. Foreign Service Posts and arranges for prompt publication of all specific investment opportunities reported by these Posts and by U.S. Trade and Investment Missions to particular countries. A copy of the A.I.D. Catalog of Investment Information and Opportunities is available in this Office as well as in each of the 42 regional Commerce Field Offices. Firms seeking counsel in respect to investing abroad should contact the Investment Resources Division, Office of International Investment, Bureau of International Commerce, Department of Commerce, Washington, D.C. 20230;

The network of Commercial Officers assigned to our diplomatic and consular establishments abroad;

Field Offices in 42 cities of the United States (see below);

The Office of International Regional Economics, which puts out the *Overseas Business Reports* (a series of pamphlets providing basic and authoritative information on specific countries) useful to exporters, importers, manufacturers and researchers as well as investors, and all who are concerned with international trade or otherwise require information about economic conditions throughout the world;

The Commercial Intelligence Division, which can furnish *World Trade Directory Reports* containing commercial and financial information on specific foreign firms or individuals;

The Business and Defense Services Administration, which provides guidance on and analyses of the economic factors relating to the sale, purchase or marketing of a specific commodity in foreign countries, or to investment in production facilities for specific commodities;

The *Checklist,* a bibliography and handy reference to the hundreds of published reports available to the U.S. business community interested in world trade and overseas investment;

International Commerce, the leading weekly periodical published in the International Affairs area of the Department of Commerce. *International Commerce* contains practical and concise international marketing information, news and reports explaining potential advantages to U.S. businessmen in profitable international sales of U.S. products, and regularly lists new investment opportunities around the world.

A Businessmen's Information Center has been established in the *Agency for International Development* to provide assistance to potential investors and other interested businessmen, and to guide them to other appropriate offices and individuals. The Center is located in Room 2926, New State Department Building, 21st and Virginia Avenue, N.W., Washington, D.C., 20523, telephone DUdley 3-4291.

AID has authority under Section 231 of the Foreign Assistance Act of 1961 to share (up to 50%) in the cost of surveys of investment opportunities.

Under Sections 221-224 of the Foreign Investment Act of 1961, AID is authorized to guarantee investments in the economies of friendly less-developed countries against certain political and business risks; including inconvertibility of foreign currency, loss by expropriation or confiscation, and loss due to war, revolution, or insurrection.

Under Section 104(e), Title I of Public Law 480, certain of the foreign currencies received by the U.S. Government in payment for agricultural commodities may be lent to U.S. businesses to develop business and expand trade. These "Cooley" funds are currently (1969) available in Korea, India, Israel, Pakistan, Congo, Ghana, Morocco, and Tunisia.

If dollar financing is *not* available on reasonable terms from private or other public sources, AID has authority under Sections 201 and 251 to make dollar loans to private (as well as public) enterprise, both U.S. and foreign. The *Export-Import Bank* of Washington may extend long-term direct loans to cover the dollar costs of equipment and services of U.S. origin. The manual entitled "Feasibility Studies, Economic and Technical Soundness Analysis, Capital Projects" is available from AID as a guide for use in preparing feasibility studies for loan applications.

Inquiries regarding these AID programs should be addressed to the Private Investment Center, Agency for International Development, Washington, D.C. 20523.

U.S. Department of Commerce Field Offices

Alburquerque, New Mexico 87101
U.S. Courthouse
Area Code 505 Tel. 247-0311

Anchorage, Alaska 99501
306 Loussac-Sogn Building
Area Code 907 Tel. 272-6331

Atlanta, Georgia 30303
4th Floor, Home Savings Building
75 Forsyth Street, N.W.
Area Code 404 Tel. 526-6000

Baltimore, Maryland 21202
305 U.S. Customhouse
Gay and Lombard Streets
Area Code 301 Tel. Plaza 2-8460

Birmingham, Alabama 35205
Suite 200-201, 908 South 20th Street
Area Code 205 Tel. 325-3327

Boston, Massachusetts 02110
Room 230, 80 Federal Street
Area Code 617 Tel. CA 3-2312

Buffalo, New York 14203
504 Federal Building
117 Ellicott Street
Area Code 716 Tel. 842-3208

Charleston, South Carolina 29403
Federal Building, Suite 631
334 Meeting Street
Area Code 803 Tel. 747-4171

Charleston, West Virginia 25301
3002 New Federal Office Building
500 Quarrier Street
Area Code 304 Tel. 343-6196

Cheyenne, Wyoming 82001
6022 Federal Building
2120 Capitol Avenue
Area Code 307 Tel. 634-5920

Chicago, Illinois 60604
1486 New Federal Building
219 South Dearborn Street
Area Code 312 Tel. 828-4400

Cincinnati, Ohio 45202
8028 Federal Office Building
550 Main Street
Area Code 513 Tel. 684-2944

Cleveland, Ohio 44101
4th Floor, Federal Reserve Bank Bldg.
East 6th Street and Superior Avenue
Area Code 216 Tel. 241-7900

Dallas, Texas 75202
Room 1200, 1114 Commerce Street
Area Code 214 Tel. RIverside 9-3287

Denver, Colorado 80202
16407 Federal Building
20th and Stout Streets
Area Code 303 Tel. 297-3246

Des Moines, Iowa 50309
1216 Paramount Building
509 Grand Avenue
Area Code 515 Tel. 284-4222

Detroit, Michigan 48226
445 Federal Building
Area Code 313 Tel. 226-6088

Greensboro, North Carolina 27402
412 U.S. Post Office Building
Area Code 919 Tel. 275-9111

Hartford, Connecticut 06103
18 Asylum Street
Area Code 203 Tel. 244-3530

Honolulu, Hawaii 96813
202 International Savings Building
1022 Bethel Street
Tel. 588977

Houston, Texas 77002
5102 Federal Building
515 Rusk Avenue
Area Code 713 Tel. 228-0611

Jacksonville, Forida 32202
512 Greenleaf Building
208 Laura Street
Area Code 904 Tel. 354-7111

Kansas City, Missouri 64106
Room 2011, 911 Walnut Street
Area Code 816 Tel. FR 4-3141

Los Angeles, California 90015
Room 450, Western Pacific Building
1031 South Broadway
Area Code 213 Tel. 688-2833

Memphis, Tennessee 38103
345 Federal Office Building
167 North Main Street
Area Code 901 Tel. 534-3214

Miami, Florida 33130
928 Federal Office Building
51 S.W. First Avenue
Area Code 305 Tel. 350-5267

Milwaukee, Wisconsin 53203
Straus Building
238 West Wisconsin Avenue
Area Code 414 Tel. BR 2-8600

Minneapolis, Minnesota 55401
306 Federal Building
110 South Fourth Street
Area Code 612 Tel. 334-2133

New Orleans, Louisiana 70130
909 Federal Office Building, South
610 South Street
Area Code 504 Tel. 527-6546

New York, New York 10001
61st Floor, Empire State Building
350 Fifth Avenue
Area Code 212 Tel. LOngacre 3-3377

Philadelphia, Pennsylvania 19107
Jefferson Building
1015 Chestnut Street
Area Code 215 Tel. 597-2850

Phoenix, Arizona 85025
5413 New Federal Building
230 North First Avenue
Area Code 602 Tel. 261-3285

Pittsburgh, Pennsylvania 15222
2201 Federal Building
1000 Liberty Avenue
Area Code 412 Tel. 644-2850

Portland, Oregon 97204
217 Old U.S. Courthouse
520 S.W. Morrison Street
Area Code 503 Tel. 226-3361

Reno, Nevada 89502
2028 Federal Building
300 Booth Street
Area Code 702 Tel. 784-5203

Richmond, Virginia 23240
2105 Federal Building
400 North 8th Street
Area Code 703 Tel. 649-3611

St. Louis, Missouri 63103
2511 Federal Building
1520 Market Street
Area Code 314 Tel. MA 2-4243

Salt Lake City, Utah 84111
3235 Federal Building
125 South State Street
Area Code 801 Tel. 524-5116

San Francisco, California 94102
Federal Building, Box 36013
450 Golden Gate Avenue
Area Code 415 Tel. 556-5864

Santurce, Puerto Rico 00907
Room 628, 605 Condado Avenue
Tel. 723-4640

Savannah, Georgia 31402
235 U.S. Courthouse and
Post Office Building
125-29 Bull Street
Area Code 912 Tel. 232-4321

Seattle, Washington 98104
809 Federal Office Building
909 First Avenue
Area Code 206 Tel. 583-5615

APPENDIX F

DIRECTORY OF MANUFACTURERS

N.B. No warranty is made regarding the completeness or accuracy of this list. Inclusion or rejection implies neither endorsement nor rejection by the authors or by the Agency for International Development.

Ref No.	
2	A. B. & I. Plastics 7091 Central Avenue Newark, California 94560
2	ASC Plastics, Inc. N. 800 Fancher Way Spokane, Washington 99211
2	Adams Brothers Co., Inc. P. O. Box 63 Eads, Tennessee 38028
1	Airco Chemicals and Plastics 150 East 42nd Street New York, New York 10017
4	Akron Extruders 1119 Milan Street Canal Fulton, Ohio 44614
1	Allied Chemical Corp. Plastics Div., Columbia Rd. Morristown, N. J. 07960
1	American Chemical Corp. P. O. Box 9247 Long Beach, California 90810
2	Amoco Chemicals Corporation Industrial Products Division 1530 Commerce Drive Stow, Ohio 44224

Ref No.	
2	Anesite Division, Clow Corp. 6200 Mulford Street Chicago, Illinois 60648
4	Anger APM U.S. Anger, Inc. 8255 West 20th Avenue P. O. Box 4246 Hialeah, Florida 33104
2	Arrow Industries 44 East 6th Avenue P. O. Box 217 Midvale, Utah 84047
4	Bolling, Stewart, & Co. 3190 E. 65th Street Cleveland, Ohio 44127
1	Borden Inc/Chemical Div. Thermoplastic Products 511 Lancaster Street Leominster, Mass. 01453
21	Borg-Warner Pipe & Products Dept. of Fabricated Products Div. of Borg-Warner Corp. 1524 Crystal Avenue Kansas City, Missouri 64126

Note: See Reference Numbers at End of Appendix F.

Ref No.	
2,5	Cabot Piping Systems Plastics Div., Cabot Corp. P. O. Box 1032 Louisville, Kentucky 40201
2	Can-Tex Industries Division of Harsco Corp. Plastic Pipe Division Mineral Wells, Texas 76067
2	Cardinal Plastics, Inc. P. O. Box 7197 Denver, Colorado 80207
2	Carlon Products Conoco Plastics, Div. of Continental Oil Company P. O. Box 236, Cottage Row Wilton, Connecticut 06897
2	Carmel Industries, Inc. 4851 N. W. 36th Avenue Miami, Florida 33142
1	Celanese Plastics Company 550 Broad Street Newark, New Jersey 07102
2	Celanese Plastics Company 4550 Cemetery Road Hilliard, Ohio 43026
2	Certain-Teed Products Corp. Certain-Teed Asbestos and Plastics Division 500 W. First Street P. O. Box 988 McPherson, Kansas 67460
2	Charlotte Pipe & Foundry Co. P. O. Box 991 Monroe, North Carolina 28110
2	Colonial Plastics Mfg. Co. P. O. Box 15415 Hilldale Sta. 5128 W. Hanna Avenue Tampa, Florida 33614
1	Conoco Plastics Div. Continental Oil Co. P. O. Box 236 Cottage Row Wilton, Connecticut 06897
2	Continental Plastics Industries, Inc. 1300 40th Street Denver, Colorado 80205

Ref No.	
2	Cresline Plastic Pipe Company, Inc. 955 Diamond Avenue Evansville, Indiana 47711
2	Crown-Line Plastics, Inc. Industrial Site Nebraska City, Nebraska 68410
4	Davis-Standard/Goulding Crompton & Knowles Corp. Rte. 1, Pawcatuck, Connecticut 02891
1	Diamond Shamrock Corp. Union Commerce Bldg. Cleveland, Ohio 44115
2	Dixie Plastics Mfg. Company, Inc. P. O. Box 52769 New Orleans, La. 70150
1	The Dow Chemical Co. P. O. Box 467 Midland, Michigan 48641
3	E. I. duPont de Nemours & Co., Plastics Dept. Wilmington, Delaware 19898
2	Durapipe & Fittings Ltd. Bentinck Road West Drayton, Middx. England
1	Eastman Chemical Products, Inc. Sub. of Eastman Kodak Co. Kingsport, Tenn. 37662
4	Egan Machinery Co. S. Adamsville Road Somerville, N. J. 08876
2	Electric Hose & Rubber Co. Wilmington, Delaware 19899
2	Empresas Rasado, Inc. P. O. Box 952 Carolina, Puerto Rico 06630
1	Escambia Chemical Corp. P. O. Box 467 Pensacola, Florida 32502
1	Ethyl Corporation Research and Development P. O. Box 341 Baton Rouge, La. 70821

Ref No.	
2	Ethyl Corporation Plastics Division Pipe Products Ethyl Tower, 451 Florida St. Baton Rouge, La. 70821
4	Fellows Gear Shaper Co. 78 River St. Springfield, Vermont 05156
2	Fibre-Tek Corporation 1711 Anaheim Avenue Costa Mesa, Calif. 92627
1	Firestone Plastics Company Chemicals Division P. O. Box 699 Pottstown, Pennsylvania 19464
2	The Flintkote Company Pipe Products Group Orangeburg, N. Y. 10962
2	Florida Extrusion Corp. 120 N.W. 11th Street P. O. Box 758 Boca Raton, Florida 33432
2	Four D Mfg. Company 209 1/2 Fourth Street Parkersburg, W. Va. 26101
2	Four D West, Inc. Morgan, Utah 84050
2	Gaspro, Ltd. P. O. Box 2454 Honolulu, Hawaii 96804
1	The General Tire & Rubber Company Chemical/Plastics Div. P. O. Box 951 Akron, Ohio 44309
2	Genova Products 300 Rising Street Davison, Michigan 48423
4	Getty Machine & Mold, Inc. 384 Getty Avenue Clifton, N. J. 07015
2	Gifford-Hill Western Dev. Gifford-Hill & Co., Inc. 2425 Marshall Street P. O. Box 2748 Lubbock, Texas 79408

Ref No.	
2	Glamorgan Plastics A Div. of Glamorgan Pipe and Foundry Co. P. O. Box 740 Lynchburg, Virginia 24505
2	Goodall Rubber Company Plastics Division 2320 E. State Street Trenton, New Jersey 08604
3	B. F. Goodrich Chemical Co. 3135 Euclid Avenue Cleveland, Ohio 44115
1	The Goodyear Tire & Rubber Company Chemical Division Akron, Ohio 44316
1	Gulf Oil Company U. S. Chemicals Department Plastics Division P. O. Box 2100, Gulf Bldg. Houston, Texas 77001
2	Harvel Plastics Inc. P. O. Box 757 Easton, Pa. 18042
2	Haskon Incorporated Middletown Industrial Park Middletown, Delaware 19709
1	Hercules Incorporated Wilmington, Delaware 19899
4	Hobbs Mfg. Co. 666 Lincoln St. Worcester, Mass. 01605
2	Hurricane Pipe Mfg. Inc. 1250 N.W. 23rd Avenue Ft. Lauderdale, Florida 33311
2	Induplas de Carolina, Inc. P. O. Box 243 La Fatima Ponce, Puerto Rico 00731
2	Interstate Plastic Inc. P. O. Box 942 Coeur D'Alene, Idaho 83814
2	Jet Stream Plastics Div. of Ralph Jones Co., Inc. P. O. Box 190 Siloam Springs, Ark. 72761

Ref No.	
2	Johns-Manville Sales Corp. Pipe Division 22 E. 40th Street New York, New York 10016
4	Johnson Div./Leesona Corp. P. O. Box 490 Chippewa Falls, Wisconsin 54729
2	Kerona, Inc. 2547 W. Jackson Street Phoenix, Arizona 85009
	Kerona Plastic Extrusion, Co. 2050 East Fremont Street Stockton, Calif. 95205
2	Lasco Industries 1561 Chapin Road Montebello, Calif. 90054
2	Linehan Plastic Corp. 2062 Irving Blvd. Dallas, Texas 75207
1	Marbon Division Borg-Warner Corp. P. O. Box 68 Washington, W. Va. 26181
2	Micro Tool Company Dura Plastic Products 533 East Third Street Beaumont, California 92223
2	Mid-American Industries, Inc. P. O. Box 13224 Memphis, Tennessee 38113
2	Mirada Enterprises P. O. Box 392 La Mirada, Calif. 90638
1	Mobil Chemical Company 150 East 42nd Street New York, New York 10017
4	Modern Plastic Machinery Corp. 64 Lakeview Avenue Clifton, N. J. 07105
1	Monsanto Company Plastics Division P. O. Box 1531 Springfield, Mass. 01101

Ref No.	
1	H. Muehlstein & Co., Inc. 475 Steamboat Road Greenwich, Connecticut 06830
4	NRM Corp. 47 W. Exchange St. Akron, Ohio 44308
2	Nalgene Piping Systems Div. of Nalge Co., Inc. 75 Panorama Creek Drive P. O. Box 365 Rochester, New York 14602
2	Nebraska Plastics, Inc. Cozad, Nebraska 69130
2	Olin Evanite Plastics P. O. Box 217 Carrollton, Ohio 44615
2	Pacific Plastic Pipe Company P. O. Box 399 Beaverton, Oregon 97005
2	Pacific Western Extruded Products, Inc. 9750 Firestone Blvd. Downey, Calif. 90241
2	Peerless Plastics, Inc. P. O. Box 956 Garden City, Kansas 67846
2	Perma-Pipe Corp. 1609 Stoneridge Drive Stone Mountain, Ga. 30083
1	Phillips Petroleum Company Chemical Dept., Plastics Div. Bartlesville, Oklahoma 74003
2	Phillips Products Co., Inc. Sub. of Phillips Petroleum Company Bartlesville, Oklahoma 74003
2	The Plastex Division Vistron Corporation 3232 Cleveland Avenue Columbus, Ohio 43224
2	Plastic Industries, Inc. 2615 N. E. 5th Avenue Pompano Beach, Florida 33064

Ref No.	
2	Plastics Industries of Delaware, Inc. Heller Road Interstate Industrial Park Bellmawr, New Jersey 08030
2	Plasticos Metropolitanos, Inc. P. O. Box 21031 Rio Piedras, Puerto Rico 00928
2	Plastic Specialties Manufacturing Corp. 4000 Metzger Road Fort Pierce, Florida 33450
2,5	Plastiline, Inc. 1251 N. E. 48th Street Pompano Beach, Florida 33064
2	Portco Corporation Vancouver, Washington 98660
2	Precision Polymers, Inc. P. O. Box 237 Rockaway, New Jersey 07886
4	Prodex Div. Koehring Co. King George Post Road Fords, New Jersey
2	Pyramid Industries Inc. P. O. Box 321 Erie, Pennsylvania 16505
2	Pyramid South, Inc. P. O. Box 848 Benton, Arkansas 72015
2	Race & Race, Inc. P. O. Box 1400 Winterhaven, Florida 33880
2	Ralon Products, Inc. 635 E. Edna Place Covina, Calif. 91722
2	Razorback Plastic Products, Inc. 3730 Wheeler Avenue Fort Smith, Arkansas 72901
2	Rea Plastics, Inc. P. O. Box 766 Kingsport, Tennessee 37662

Ref No.	
4	Reifenhauser, U.S. Sales Corp. 60 E. 42nd Street New York, New York 10017
4	Reliable Rubber & Plastic Machinery Company 2014 Union Tpk. N. Bergen, New Jersey 07047
2	Richco Plastic Company 5825 N. Tripp Avenue Chicago, Illinois 60646
2	Ridge Plastics Company P. O. Box 2205 Highway 18 East Jonesboro, Arkansas 72401
2	Rite-Flo Mfg. Corp. 13020 S. W. 87th Avenue Miami, Florida 33156
4	Royle, John, & Sons 10 Essex Street Patterson, N. J. 07501
2	Ruth-Berry Pump Company 341 E. Brooks Road P. O. Box 9056 Memphis, Tennessee 38109
4	Sakas, Inc. P. O. Box 158 Somerset, Ohio 43783
2	Sedco Corporation P. O. Box 365 Auburndale, Florida 33823
2	Silver-Line Plastics Corp. Post Office Box 1806 Asheville, N. Carolina 28802
2	Simpson Timber Company Plastics Division 4421 Nugget Way Eugene, Oregon 97403
1	Sinclair-Koppers Company Pittsburgh, Pa. 15219
2,5	R. & G. Sloane Mfg. Div. The Susquehanna Corp. 7606 N. Clybourn Avenue Sun Valley, Calif. 91352

Ref No.	
2	A. O. Smith-Inland Inc. Reinforced Plastic Division 2700 West 65th Street Little Rock, Arkansas 72209
1	Stauffer Chemical Company Plastics Division Post Office Box 320 Delaware City, Del. 19706
4	Sterling Extruder Corp. 1537 W. Elizabeth Avenue Linden, N. J. 07036
2	Superlon-Pipe Corporation 401 Alexander Avenue Building 323 Tacoma, Washington 98421
2	The Swanson Company 3747 Buckeye Road P. O. Box 6557 Phoenix, Arizona 85005
2	Telsco Industries P. O. Box 18205 Dallas, Texas 75218
4	Tennant, C., Sons & Co. of New York, Omni Div. 100 Park Avenue New York, N. Y. 08903
1	Tenneco Plastics Division Tenneco Manufacturing Co. P. O. Box 2 Piscataway, N. J. 08854
2	ThermoPlastics Corp. 1 Rodney Blvd. Southland Industrial Park Charlotte, N. C. 28210
2	Thogus Products Company 1374 W. 117th Street Cleveland, Ohio 44107
1	Thompson Plastics Olin Corporation Assonet, Massachusetts 02702
2	Triangle Conduit & Cable Co., Inc. Plastic Pipe Division Triangle & Jersey Avenues New Brunswick, N. J. 08903

Ref No.	
2	Typhoon Products P. O. Box 477 Miami Springs, Florida 33166
1	U. S. Industrial Chemicals Company, Div. of Nat'l Distillers & Chemical Corp. Tuscola, Illinois 61953
2	U. S. Plastics, Inc. P. O. Box 152 Houston, Mississippi 38851
1	Union Carbide Corp. Plastics Div., 270 Park Ave. New York, New York 10017
2	Union Malleable Mfg. Co. Plastic Division Ashland, Ohio 44805
1	Uniroyal Chemical Division of Uniroyal, Inc. Naugatuck, Conn. 06770
2	United Technology Center Div. of United Aircraft Corp. P. O. Box 5222 Sunnyvale, Calif. 94088
2	Universal Pipe & Plastics, Inc. P. O. Box 356 Hillsboro, Texas 76645
2	Vinylite Corporation 3121 South Oak Street Santa Ana, Calif. 92707
2	Virginia Plastics Company P. O. Box 165 Roanoke, Virginia 24002
4	Waldron-Hartig Div. Medland-Ross Corp. Web Processing Section P. O. Box 791 New Brunswick, N. J. 08903
4	Welding Engineers, Inc. P. O. Box 391 Norristown, Pa. 19404
4	Welex, Inc. 100 Queens Drive King of Prussia, Pa. 19406

Ref No.

4 Werner & Pfleiderer Corp.
160 Hopper Avenue
Waldwick, N. J. 07463

2 Wesflex Manufacturing Co.
P. O. Box 1009
Richmond, California 94802

2 Western Plastics Corp.
East 7th St. Road at
Prospect Avenue
P. O. Box 249
Hastings, Nebraska 68901

Ref No.

2 Western Plastics Corp.
2330 Port of Tacoma Road
Tacoma, Washington 98421

2 Woodward Corporation
Woodward, Alabama 35189

Reference Numbers

[1]Manufacturer of plastic materials for pipe for potable water.

[2]Manufacturer of plastic pipe and/or fittings for potable water.

[3]Manufacturer of plastic materials and plastic pipe and/or fittings for potable water.

[4]Manufacturer of extruders, injection molders, postforming, or other equipment for manufacture of plastic pipe or fittings.

[5]Manufacturer of molds for plastic pipe fittings.

APPENDIX G

*NATIONAL SANITATION FOUNDATION

STANDARD NUMBER 14
for
Thermoplastic Materials, Pipe, Fittings, Valves, Traps, Joining Materials and Appurtenances

Section 1. GENERAL

1.01 PURPOSE: To establish the necessary public health and safety requirements for thermoplastic materials, pipe, fittings, valves, traps, joining materials and appurtenances based on specific end use and application, and to provide for conditions and provisions of evaluation therefor.

1.02 COVERAGE: Coverage shall include, but not be limited to, thermoplastic materials, pipe, fittings, valves, traps, joining materials and appurtenances intended for use in:

1.021 Potable water systems.
1.022 Drainage and vent systems.

1.03 MINIMUM REQUIREMENTS: The requirements and conditions set forth in this Standard are the minimum necessary to adequately protect and insure the continued protection of the public's health and safety. These are minimum requirements and variations may be approved when they tend to make items more resistant to use conditions, corrosion, or more suitable for the intended end use. Units which have components or parts which are covered under existing NSF Standards or Criteria shall comply with the applicable requirements thereof, but shall be evaluated under the provisions of said other Standard or Criteria.

1.04 STANDARD REVIEW: A complete review of the Standard shall be conducted at intervals of not more than three years to determine what changes, deletions or additions if any, are necessary to maintain current and effective requirements consistent with new technology and progress. These

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*Note: This extract is *not* complete and is presented for information only. Manufacturers, users, and others interested in the National Sanitation Foundation (NSF) Seal of Approval Program should contact NSF directly. Use of the NSF Seal is solely controlled by the NSF.

reviews shall be conducted by appropriate representatives from the industry, public health, and user groups. Final adoption of revision shall be in accordance with the procedures established by the National Sanitation Foundation Joint Committee on Plastics.

1.05 AMENDMENTS AND ADDITIONAL REQUIREMENTS: Amendments to and additional requirements in this Standard may be effected in accordance with the procedures established by the National Sanitation Foundation Joint Committee on Plastics. Prior to their adoption all amendments and/or additional requirements shall be reviewed by appropriate representatives from the industry, public health and user groups. Adoption shall be in accordance with the established procedures and at the recommendation of the National Sanitation Foundation Joint Committee on Plastics.

Section 2. DEFINITIONS

2.00 APPURTENANCE: The word "appurtenance" shall be defined to include, but not limited to, water conditioning tanks, dip tubes, reservoir floats and storage tanks.

2.01 CHEMICAL ANALYSIS: The term "chemical analysis" shall mean and include such qualitative and/or quantitative analysis of chemicals present in thermoplastic materials, pipe, fittings, valves, traps, joining materials and appurtenences or in the extracted waters therefrom; as may be deemed necessary.

2.02 COMPOUND: An intimate admixture of a resin with other ingredients, such as fillers, softeners, stabilizers, plasticizers, catalysts, pigments, and/or dyes.

2.03 COMPOUNDER: A corporation, company or individual, who under the provisions of this Standard, further blends, mixes, or otherwise modifies Listed materials as supplied by a raw material manufacturer.

2.04 CONTAMINATION: The presence of foreign materials, impurities, or dilutions which might affect one or more of the physical, chemical toxicological, or taste and odor properties of the thermoplastic material, pipe, fittings, valves, traps, and/or joining materials.

2.05 DRAINAGE SYSTEM: The piping within public or private premises which conveys sewage, rain water, or other liquid wastes to a legal point of disposal, but does not include the mains of a public sewer system or private or public sewage treatment or disposal plant.

2.06 FITTING: A device used to join or terminate sections of pipe.

2.07 HYDROSTATIC DESIGN STRESS: The maximum long term stress considered safe in the wall of the pipe in the circumferential orientation due to internal hydrostatic pressure as determined by the method presented in Appendix A.

2.08 JOINING MATERIAL: A substance which will effect a weld or bond between two parts.

2.09 MANUFACTURER (EXTRUDER-MATERIAL SUPPLIER-MOLDER): A corporation, company, or individual, who under the provisions of the Standard, manufactures thermoplastic materials, pipe, fittings, valves, traps, joining materials and appurtenances.

2.10 ORGANOLEPTIC: The work "organoleptic" shall mean pertaining to evaluation of taste and odor producing properties.

2.11 PLASTIC: A material that contains as an essential ingredient an organic substance of high molecular weight, is solid in its finished state, and, at some stage in its manufacture or in its processing into finished articles, can be shaped by flow.

2.12 PLASTIC PIPE: A hollow cylinder of plastic compound in which the wall thicknesses are usually small in comparison with the diameter, and in which the outside and inside walls are essentially concentric* and which is covered by an applicable physical standard.

2.13 POTABLE WATER SYSTEMS: Potable Water Systems shall refer to those water systems intended to convey drinking water or water for culinary and/or food processing purposes. It shall include pipe, fittings, valves, and other accessories as are normally considered a part of a water supply system.

2.14 RESIN: A solid, semisolid, or pseudosolid organic material which has an indefinite and often high molecular weight, exhibits a tendency to flow when subjected to stress, usually has a softening or melting range, and usually fractures conchoidally. As used herein, resin shall mean the basic thermoplastic which must be mixed with other ingredients before it is suitable for the manufacture of finished product.

2.15 SPECIAL ENGINEERED: The term "special engineered" shall mean specifically designed for a particular end use or application.

2.16 THERMOPLASTIC: A plastic which is capable of being repeatedly softened by an increase of temperature and hardened by a decrease of temperature.

2.17 TOXIC: The word "toxic" shall refer to the adverse physiological effect to man.

2.18 TRAP: A fitting or device so designed and constructed as to provide, when properly vented, a liquid seal which will prevent the back passage of air without materially affecting the flow of liquid through it.

2.19 VALVE: A device used to regulate flow of liquids or gases.

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*Note: Plastic pipe shall be considered to mean any cylindrical conduit having a nominal diameter of ½ inch or greater; provided, however, that when applicable, U.S. Dept. of Commerce Commerical Standards specifically provide for plastic pipe of smaller nominal diameter, the smallest diameter specified therein, shall govern.

2.20 VENT SYSTEM: Pipe or pipes installed to provide a flow of air to or from a drainage system, to provide a circulation of air within such system and to protect trap seals from siphonage and back pressure by limiting air pressure differentials to plus or minus 1 inch of pressure measured in inches of water.

Section 3. MATERIALS

3.00 GENERAL: Materials used in manufacture of pipe, fittings, valves, traps, joining materials and appurtenances covered by this Standard shall meet the specific public health and safety as well as performance requirements as established herein for the intended end use or application. All such materials shall be manufactured in a manner which will prevent introduction of possible contamination thereto.

3.001 Such quality procedures and reports are as deemed necessary to continued uniform quality of the materials and continued compliance with the applicable ASTM requirements for said material may be required.

3.002 The addition of innocuous tracers to materials covered by this Standard may be required when so recommended by the NSF Joint Committee on Plastics.

3.003 The manufacturer shall submit, at the time of requesting evaluation and qualification of a thermoplastic material and/or joining material, complete formulation information for such material. When any change is made in the formula or in the source of supply of ingredients therein, such additional information shall also be submitted. Said information shall be retained on a confidential basis.

3.01 HYDROSTATIC DESIGN STRESS: Each manufacturer of a material intended for use in the manufacturing of plastic pipe intended for pressure applications under the provisions of this Standard shall submit evidence or data to permit the assignment of a design stress in conformance with "Methods for Estimating Long-Term Strength and Working Stress of Thermoplastic Pipe" (Appendix A). The assignment of design stress under the provision of this requirement shall not constitute acceptance of pipe extruded from the same material by others.

3.02 POTABLE WATER APPLICATION: Thermoplastic materials for pipe, fittings, valves, joining materials and/or appurtenances for potable water applications shall contain no ingredients in an amount which has been demonstrated to migrate into water in quantities which are considered toxic and shall conform to the following specific requirements:

3.021 TOXICOLOGICAL AND ORGANOLEPTIC* The toxicological and organoleptic evaluations of the analyses specified in Appendix B shall meet minimum public health requirements.

*The procedures established in Appendix B and as reported in "A Study of Plastic Pipe for Potable Water Supplies," are based upon long term evaluation of thermoplastic materials for potable water applications as to their suitability from a public health and use standpoint.

3.022 PHYSICAL REQUIREMENTS: Thermoplastic materials shall comply with the physical, chemical and performance requisites of the latest applicable Standard(s) of the American National Standards Institute (ANSI); American Society of Testing Materials (ASTM); or the Commodity Standards Division of the U.S. Department of Commerce (CS); as determined by the NSF Joint Committee on Plastics.

3.03 DRAINAGE AND VENT SYSTEM APPLICATIONS: Thermoplastic materials for pipe, fittings, traps, valves, joining materials and appurtenances shall comply with the physical, use resistant and application requirements of the latest applicable ANSI, ASTM, or CS Standard(s) as determined by the NSF Joint Committee on Plastics.

3.04 MATERIALS PRODUCED BY COMPOUNDER: Thermoplastic materials produced by a compounder shall meet all of the applicable foregoing requirements of this Standard and shall in addition, meet the following specific requirements:

3.041 Samples for toxicological and organoleptic evaluation may be collected from each batch of compound made from separate lots of material received from the material suppliers. Not less than two complete toxicological and organoleptic evaluations shall be conducted within the period of one year.

3.042 Such quality control procedures and reports may be required as are deemed necessary to assure continued uniform quality of the materials and continued compliance with the latest applicable ANSI, ASTM, or CS Standard(s) as determined by the NSF Joint Committee on Plastis.

3.043 Periodic reports from the compounder shall be required as to the quantity of basic resin purchased, products sold, produced, and in stock. The compounder shall also permit requests for similar information relative to the quantity of basic resin and other ingredients purchased from prime suppliers.

Section 4. REQUIREMENTS FOR PIPE, FITTINGS, VALVES & TRAPS

4.00 GENERAL: Thermoplastic pipe, fittings, valves, traps and appurtenances shall be produced only from virgin materials meeting the requirements of this Standard for the use intended. Clean rework material, of the same virgin ingredients generated from the manufacturer's own production may be used by the same manufacturer provided that the finished products are equal in quality to products manfactured from virgin material.

4.01 TOXICOLOGICAL AND ORGANOLEPTIC REQUIREMENTS: Thermoplastic pipe, fittings, valves, and appurtenances, intended for potable water application shall conform to the toxicological and organoleptic requirements established in Items 3.02, 3.021, and 3.022 for the thermoplastic materials used for potable water applications.

4.02 PHYSICAL, PERFORMANCE, AND DIMENSION REQUIREMENTS: All pipe, fittings, valves, and traps under this standard, shall comply with the physical, performance, and dimension requirements of the latest applicable ANSI, ASTM, or CS Standard(s) as determined by the NSF Joint Committee on Plastics. When such Standards are not available for a particular category of end use, the NSF Joint Committee on Plastics shall consider the problem and make proper recommendations in the best interests of the public's health.

4.03 MARKING AND CODING OF PIPE*, FITTINGS AND TRAPS, AND APPURTENANCES: The manufacturer shall place on all thermoplastic pipe, fittings, valves and traps, and appurtenances, the designations and identification required in the lastest applicable ANSI, ASTM, or CS Standard(s) as determined by the NSF Joint Committee on Plastics. PROVIDED, HOWEVER, THAT FITTINGS AND VALVES OF SUCH SIZE AND/OR CONFIGURATION AS TO PRECLUDE USE OF THE COMPLETE MARKING SHALL BE AT LEAST IDENTIFIED AS TO MANUFACTURER AND TYPE OF MATERIAL.

4.031 All required markings shall be legible and so applied as to remain legible under normal handling and installation practices.

4.032 Thermoplastic pipe, in addition to the above, shall bear an appropriate code which will assure identification on the pipe as to the month of production and resin formulas used in the production of said pipe. Manufacturer shall maintain such additional records as are necessary to confirm identification of all pipe so coded. Such records shall be made available to the Laboratory upon request.

4.04 SPECIAL ENGINEERED PIPE, FITTINGS, VALVES AND TRAPS: Variations in design of thermoplastic pipe, fittings, valves and traps may be permitted when the requirements of the intended end use dictate said variance and when thermoplastic pipe, fittings, valves, traps manufactured in conformance with existing standards will not provide a product satisfactory for said intended use. The variation shall be permitted only upon specific application by the manufacturer. The manufacturer of proposed special engineered pipe, fittings, valves and traps, shall submit complete design engineering considerations for said special engineered items.

4.041 Special testing may be required of the pipe, fittings, valves, traps, and appurtenances submitted under the provisions of Item 4.04. Such special testing shall be in keeping with the most applicable requirements of Item 4.02.

4.042 Special engineered products shall be identified by the symbol "SE" immediately following the appropriate product identification.

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*NOTE: The following indicates the required markings and code information:

Pipe Size	Type Material	Pressure PSI	Commercial Std. No.	Trade Name	Code	nSf Logo
	Example:					
2"	pvc 1120	200 psi	CS256-63	JCY	1510A	nSf

4.05 SPECIAL TEST REQUIREMENTS: Special tests may be required on thermoplastic pipe, fittings, valves, traps and appurtenances when recommended by the NSF Joint Committee on Plastics, when deemed necessary to assure adequate protection of the public's health and safety.

Section 5. JOINING MATERIALS

5.00 GENERAL: Joining materials covered in the Standard shall, under conditions of use application, conform to the material requirements set forth in Section 3 of this standard for the appropriate intended end use. Joining materials covered by this Standard shall, in addition, comply with the pertinent requirements of the latest applicable ANSI, ASTM, or CS Standard(s) as determined by the NSF Joint Committee on Plastics.

5.01 PHYSICAL AND PERFORMANCE REQUIREMENTS: Joining materials shall, when used as directed by the manufacturer and under use conditions, result in a satisfactory joint, bond, or weld, meeting the physical and performance requirements of pipe, fittings, valves, and/or traps being joined as established in the latest applicable ANSI, ASTM, or CS Standard(s) as determined by the NSF Joint Committee on Plastics.

5.02 PACKAGING AND IDENTIFICATION: Joining materials shall be packaged in containers which shall be identified as to content, manufacturer, and intended end use.

Section 6. QUALITY CONTROL

6.00 GENERAL: The manufacturer shall provide and maintain quality control testing facilities at each production facility.

6.01 RECORDS: The manufacturer shall maintain a record of all quality control tests conducted for a period of not less than two years.

RECOMMENDATION FOR INSTALLATION

Thermoplastic pipe, fittings, valves, traps, and joining materials meeting the requirements of this Standard will perform satisfactorily when they have been selected to meet the conditions of end use and installation, and have been installed in accordance with the manufacturer's recommendations.

A. Selection. The selection of appropriate thermoplastic pipe, fittings, valves, traps, and joining materials must take into account the following factors:
   1. Pressure requirements, including water hammer effects.
   2. Type of liquid to be conveyed.
   3. Conditions of installation, i.e. type of soil, over-head loads, terrain, wear conditions, depth of installation, and the like.
   4. Expansion and contraction of materials.
   5. Method of installation. Solvent weld, threaded, insert fittings, or combination.

B. As a general guide, the recommendations of the Plastics Pipe Institute for the installation of thermoplastic pipe, fittings, valves, and/or traps should be followed.

C. Installation. Installation of thermoplastic pipe, fittings, valves, and traps should be in conformance with state and local laws, ordinances, codes and regulations.

D. Caution should be exercised in the use of joining materials in order to prevent harm or injury to workmen during their use. The manufacturer's directions and cautions should be followed.

NSF Standard No. 14

Appendix A

METHODS FOR ESTIMATING LONG TERM STRENGTH AND WORKING STRESS OF THERMOPLASTIC PIPE

NOTE: The "Tentative Method for Estimating Long-Term Strength and Working Strength of Thermoplastic Pipe" as developed by the Thermoplastic Pipe Division of the Society of the Plastics Industry has been adopted by the NSF Joint Committee on Plastics and is hereby designated as the method to be used in determining the design stress of Thermoplastic materials to be used in pressure piping applications. The Manufacturer shall furnish evidence of design stress assignment in accordance with the provisions set forth in Item 3.01 of this Standard.

Appendix B

PROCEDURES FOR CHEMICAL–PHYSICAL–ORGANOLEPTIC–SPECTROGRAPHIC ANALYSIS OF PLASTICS

1. Specific procedures used are as reported in "A Study of Plastic Pipe for Potable Water Supplies," published by the National Sanitation Foundation, 1955.

2. The maximum acceptable concentrations of chemical substance permissible in the extractant water shall be as set forth in Public Health Service Drinking Water Standards–1962, (PHS Publication No. 956).

Policy A

National Sanitation Foundation Testing Laboratory, Inc.

January 1964

STATEMENT OF POLICY RELATING TO INSPECTION OF FACILITIES AND RECORDS

1. Actual physical inspection is required of each plant manufacturing compounds, plastic pipe, fittings, valves, traps, and/or joining material, prior to the granting of the right to use the Seal of Approval.

2. The National Sanitation Foundation Testing Laboratory reserves the right to make an inspection of a plant manufacturing materials in connection with any investigations that may be necessary relating to such materials. It is also understood that representatives may be sent to such manufacturers' warehouses to collect samples of materials bearing the National Sanitation Foundation Testing Laboratory's Seal of Approval.

3. It is understood that material manufacturers authorized to use the Seal of Approval on certain "Listed" materials will furnish the National Sanitation Foundation Testing Laboratory, upon request, with information relative to quantities, dates of delivery and like information on "Listed" raw materials purchased by any manufacturer producing "Listed" items.

4. A minimum of one inspection is required each year of product control procedures at the plant of each "Listed" manufacturer. Such additional inspections are to be made as deemed necessary by the Executive Director of the National Sanitation Foundation Testing Laboratory.

5. The Laboratory may make reasonable inspection, with or without notice, of the place or places at which "Listed" or unlisted items are made by Manufacturer and of such places under the control of the Manufacturer, including all facilities for storing, mixing, grinding, making pellets, extruding, molding, and shipping; except where Manufacturer is precluded from doing so by agreement with third parties or by government regulations and the Laboratory has been satisfied as to the validity of these restrictions.

The Laboratory shall be permitted reasonable interrogation during the inspection of persons engaged in the handling, manufacture, or procurement of a Listed item. This shall include the examination of the Listed items manufactured by others that may be in storage for resale. Access for inspections by authorized representatives of the Laboratory shall be granted by Manufacturer during production hours without undue delay. Nothing herein contained shall be construed as obligating the Manufacturer to disclose to the Laboratory or its representatives any confidential or proprietary information with respect to the Manufacturer's process or "Know-how." In the event that such confidential or proprietary information is disclosed to Laboratory, it is understood that there will be no publication of disclosure of such information without the consent of the Manufacturer.

6. The Manufacturer of products (pipe, fittings, valves, traps, and joining materials, and similar items) authorizes the Laboratory to request any and all

manufacturers of National Sanitation Foundation Testing Laboratory Listed materials (resins, compounds, and similar materials) for the production of plastic pipe, fittings, valves, traps, and/or joining materials, to reveal to the Laboratory its records of sales of plastic materials to the Manufacturer of such products.

7. The Manufacturer of products agrees to keep up-to-date records of receipts, sales, and stock on hand of Listed items, and upon demand by the Laboratory agrees to furnish such records to the Laboratory, within five (5) days after such demand, or at the option of the Laboratory agrees to permit prompt and full access to such records by the Laboratory at any time. The Laboratory agrees that information obtained shall be treated as confidential.

8. The Manufacturer of materials will submit to the Laboratory promptly on demand, an accurate and complete report of the number of pounds of Listed materials sold to any manufacturer having items Listed with the Laboratory during any prescribed period of time. Authorization for said Manufacturer to reveal this information to Laboratory is a requirement between the Laboratory and Manufacturer of Listed products. Such information received from Manufacturer of materials shall be held in confidence by the Laboratory except that reports of sales to a particular manufacturer of products may be revealed to that manufacturer, and when relevant, in any court action in which manufacturer and the Laboratory are adverse parties.

Policy B

National Sanitation Foundation Testing Laboratory, Inc.

January 1964

STATEMENT OF POLICY RELATING TO SAMPLE COLLECTION–TESTING–REPORTING

SAMPLES REQUIRED

1. Actual laboratory examination of specimens of materials offered for use in the extrusion of plastic pipe is required and actual laboratory examination of specimens of extruded plastic pipe also is required before the right to use the Seal of Approval on such materials and pipe is initially granted, and at least once a year thereafter.

2. A sample of each "Listed" raw material for making plastic pipe, fittings, valves, and/or traps will be tested at least once a year and, in addition, as frequently as may be deemed necessary by the Executive Director of the NSF Testing Laboratory. Such testing shall be at a uniform charge per sample to such material manufacturer or compounder. Provided, however, the maximum test charge per year for a listed item shall not exceed $1,000.00. A sample of each "Listed" type of Listed plastic item or joining material from each manufacturer will be tested each year at the expense of said manufacturer. Samples of Listed raw materials and Listed items may be obtained by the National Sanitation Foundation Testing Laboratory from any source deemed advisable. Required samples are to be supplied by the manufacturers of Listed materials and products without charge to the

National Sanitation Foundation Testing Laboratory. Laboratory may test and retest such samples, and those which Laboratory obtains from time to time from other sources, in the best interests of the public.

3. Compounders of polyethylene shall be limited to the use of only polyethylene resins which contain the raw material manufacturer's innocuous trace element.

4. Compounders shall be required to provide at least two (2) toicological and organoleptic samples per year, for each item Listed which is manufactured from the materials "compounded."

5. For each Listed item for which performance testing is required, one sample shall be required per year for each resin type and of each hydrostatic design stress of a given material. Blends of two (2) or more compounds in the manufacture of a product shall be considered a new compound. The sample shall be selected and prepared in accordance with the requirements of the Laboratory.

6. There shall be a distinct understanding that all samples of Listed items produced from any one general classification of materials, collected each year under all such Listed trade names, may be composited at the request of the manufacturer and examined as a single sample; in which event all products composited will be approved or disapproved on the basis of the single test result. In the event that the Laboratory accepts for Listing two (2) or more plastics as sufficiently similar for compositing and testing for toxicological and organoleptic evaluation as one sample, it is understood that all products composited will be disapproved on the basis of the single test result.

PREFORMANCE TESTING

7. Laboratory will make with reasonable promptness the performance tests to determine the physical characteristics of the pipe, fittings, valves or traps as required in the latest applicable ANSI, ASTM, or CS Standard(s) as determined by the NSF Joint Committee on Plastics.

8. Pipe, valves, fittings and traps of a material, resin type, schedule or series, pressure rating or dimension not covered by the Standard(s) enumerated above, shall meet interim performance requirements of the most applicable ANSI, ASTM, or CS Standard(s) as determined by the Laboratory and as recommended by the NSF Joint Committee on Plastics. Test pressures shall be determined on the ISO Formula and the material manufacturer's recommended stresses for short term rupture (ASTM 1599-58T) and/or 1000-hour sustained pressure tests (ASTM 1598-58T). Each separate pipe of the jet well twin pipe with the web or weld section in place shall be tested independently against the requirements of the latest applicable ANSI, ASTM, or CS Standard(s) as determined by the NSF Joint Committee on Plastics.

METHOD OF COLLECTION AND SUBMISSION

9. Toxicological and organoleptic evaluation and performance test samples shall be collected by authorized representatives of the National Sanitation Foundation Testing Laboratory.

10. Samples shall be collected at random by the authorized representative from current production, warehouse stocks, or from the field.

11. Samples shall be properly identified by an identifying stamp at the time of collection and forwarded "prepaid" by the manufacturer to the Laboratory.

REPORTING OF RESULTS AND RETESTING

12. Immediately upon completion of toxicological and organoleptic evaluation and/or performance testing, the Laboratory shall report to the Manufacturer whether the results thereof are "Satisfactory" or "Unsatisfactory." In the case the results are "Unsatisfactory" the Laboratory shall advise the manufacturer thereof, of the details of the adverse results and all particulars relating thereto that are known to the Laboratory.

13. When toxicological and/or organoleptic evaluation, or performance test is deemed "Unsatisfactory" and subsequently reported to the Manufacturer thereof, said Manufacturer shall take immediate steps to determine the cause of said "Unsatisfactory" results. The finding of said Manufacturer shall be reported to the Laboratory together with the evidence of corrective action taken within a period of not more than 30 days.

14. Retest samples may be required by the Laboratory when the results of the initial sample are deemed "Unsatisfactory." When the retest results of toxicological and/or organoleptic evaluations and/or performance samples are "Unsatisfactory," the Laboratory shall remove from its Approved-List the item(s) in question and said manufacturer shall cease to use the nSf Seal of Approval thereon. The item(s) may be reinstated on the Approved-List upon resubmission of samples as required by the Laboratory, and "Satisfactory" results are obtained upon completion of toxicological and/or organoleptic evaluations and/or performance testing thereof.

Policy C

National Sanitation Foundation Testing Laboratory, Inc.

January 1964

STATEMENT OF POLICY RELATING TO USE OF THE SEAL OF APPROVAL

1. Acting upon the report of the Executive Director covering required laboratory examinations of materials and inspections, the Board of Directors of the National Sanitation Foundation Testing Laboratory may authorize "Listing" of plastic materials or plastic items as eligible for the Seal of Approval. Manufacturers of such materials and plastic items will be advised of such "Listing" in writing and the "Listing" will be sent to health and other governmental authorities and otherwise publicized.

2. The Board of Directors of the National Sanitation Foundation Testing Laboratory reserves the right to withdraw the "Listing" of any item at any time for cause. Upon notice of the removal of an item of equipment or product from the National Sanitation Foundation Testing Laboratory's

"Listing," the manufacturer shall immediately stop applying the Seal of Approval to such "unlisted" product.

3. The Seal of Approval may be applied to cartons or other containers for "Listed" materials in the form, size, and color approved by the Laboratory. On all "Listed" plastic pipe, the Seal of Approval shall be applied to every piece at intervals of twenty-four (24) inches or less, along the length of the pipe in the size and as prescribed by the laboratory. DWV pipe shall have the prescribed nSf–DWV Seal applied at 24 inch intervals or less along the entire length of two sides of the pipe at 180° (degrees) apart or shall be marked spirally. The above insigne shall be placed at least once on each fitting in such manner as to be legible. Each Listed item, other than pipe, shall bear the Seal of Approval in the size and as prescribed by the Laboratory.

4. The National Sanitation Foundation Testing Laboratory, Inc. will use every legal means available to prevent the unauthorized use of its Seal of Approval on "unlisted" items or on "Listed" items found to be substandard.

5. When Laboratory determines, after testing, that a plastic item is in compliance with applicable requirements of the Standard, it will thereupon List said item in its public Listing of such products. In the event that removal from Listing is necessary, the Laboratory may not publish, without the express consent of the Manufacturer, any information concerning the Listed item other than such things as general composition, type, and trade name or symbol and the fact that the item has been found unsatisfactory, upon test, for use; or that the item does not conform to the requirements of the Standard.

6. Laboratory agrees to List without chemical evaluation and without extra charge, the trade name or names of items manufactured from any one of the general classifications of materials (such as polyethylene, PVC, or ABS) which is the same as that of a plastic item already Listed and paid for, unless testing of such products has already been completed for the year; in which case charges will be made for testing of new products offered for Listing.

7. Items of a material, resin type, schedule or series, pressure rating and dimension not covered by an ANSI, ASTM, or CS Standard(s) deemed applicable by the NSF Joint Committee on Plastics, shall have such a Standard under development as evidenced in a manner satisfactory to the Laboratory. Provided, however, that the Laboratory may waive said provisions when the production and use of the item in question is so limited as to make such action impractical.

8. When the provisions of Paragraph 7 of this Policy apply, the item shall meet, on an interim basis, the performance requirements of the most applicable Standard(s) of the ANSI, ASTM, or CS, as determined by the Laboratory.

9. When the most applicable Standard of ANSI, ASTM, or CS specifies only dimension and tolerance requirements, then the test pressures (if indicated), shall be determined based on the ISO formula and the manufacturer's recommended stresses for short-term rupture (ASTM 1599-58T) and/or 1000-hour sustained pressure tests (ASTM 1590-58T).

ISO Stress Formula:

$$S = \frac{P(d-t)}{2t}$$

Where S = hoop stress
P = internal pressure
d = outside diameter
t = wall thickness of the pipe

Policy D

National Sanitation Foundation Testing Laboratory, Inc.

December 1969

QUALITY CONTROL TESTING

Equipment to perform the following tests shall be in evidence and the following indicated quality control tests are required on all listed pipe, fittings, and solvent cements (See Item 5.00).

POTABLE WATER PIPE

Test	Material			
	ABS	PE	PB	PVC
Dimensions	X	X	X	X
Weight	X	X	X	X
Short-Term Rupture	X	X	X	X
Sustained Pressure	X	X	X	X
Acetone				X
Flattening Resistance	X			X

POTABLE WATER FITTINGS

Test	ABS	PVC	INSERT FITTINGS
Dimensions	X	X	X
Short-Term Rupture	X	X	X

DWV PIPE AND FITTINGS

Test	ABS	PVC
Dimensions	X	X
Weight - pipe only	X	X
Impact	-40° & 73°F.	73°F. - (and 32°F. if produced against ASTM D2665)
Short-Term Rupture	X	X
Deflection Load and Crush Resistance	X	X
Flattening Resistance (oven test)	X	X

SOLVENT CEMENTS

Test	ABS	PVC
Viscosity	X	X

The weight of pipe per coil or per specific length is a general guide as to whether or not the pipe contains an adequate amount of material to provide the minimum wall thickness if properly extruded.
Qualification test only. An independent laboratory may be used.

APPENDIX H

INSTALLATION OF PLASTICS PIPE

CONTENTS

1. INTRODUCTION

This compilation of information from industry sources, water utilities, manufacturers' literature and catalogs, American Society for Testing and Materials (ASTM) standards, Plastics Pipe Institute (PPI) reports and publications, technical journals, and personal experience is intended as a guide and checklist for those waterworks considering or using plastics pipes, particularly those waterworks, such as in developing countries, which may not have ready access to such information. Surprisingly enough, no comprehensive manual on plastics pipe for water supply use exists (or is known to the authors) although committees of both the American Water Works Association (AWWA) and the Plastics Pipe Institute (PPI) have been at this task for several years. Pending publication of these more authoritative documents, this interim report may be of some value.

2. LIBRARY

The following abbreviated list of publications (see Appendices B and C for more complete listings) should be acquired in order to design a local specification:

Adelmann, Charles B. "How to Specify and Use Plastic Pipe for Water Utilities," *Water and Wastes Engineering,* Vol. 5, No. 7, pp. 61-63 (July 1968).

Farish, Charles A. "Utiliacion de Tuberias Plasticas en Abastecimientos de Agua Potable," papers presented at symposium in Caracas, Venezuela, October 21–November 1, 1963. Published by Organization Panamericana de la Salud. (Pan American Health Organization), *Publication No. 113,* Washington, D.C., May 1965.

Mamrelli, E.S. "Plastic Pipe and Fittings, Committee Progress Report," *Journal American Water Works Association,* Vol. 59, No. 10, pp. 1238-1248 (October 1967).

*Plastics Pipe Institute. "Recommended Service (Design) Factors for Pressure Applications of Thermoplastic Pipe Materials," PPI-TR9 (October 1969).

*Plastics Pipe Institute. "Standards for Plastics Piping," Technical Report PPI-TR5 (March 1969).

*Plastics Pipe Institute. "Recommended Practice for Making Solvent Cemented Joints with Polyvinyl Chloride Plastic (PVC) Pipe and Fittings," PPI-TR10 (February 1969).

*Plastics Pipe Institute. "Recommended Hydrostatic Design Stresses for Thermoplastic Pipe Compounds for Water," Technical Report PPI-TR4 (September 1967, February 1968, and December 1968).

*Plastics Pipe Institute. "A Glossary of Plastics Piping Terms," Technical Report PPI-TR1 (November 1968).

*Plastics Pipe Institute. "Policies and Procedures for Developing Recommended Hydrostatic Design Stresses for Thermoplastic Pipe," Technical Report PPI-TR3 (July 1968).

*Plastics Pipe Institute. "Installation Procedures for Polyethylene (PE) Plastic Pipe," PPI-TR8 (April 1968).

*Plastics Pipe Institute. "Recommended Standard Dimensional Terminology for Plastics Pipe Fittings," PPI-TR6 (February 1968).

*Note: Technical Reports of the Plastics Pipe Institute are available at $1.00 each from 250 Park Avenue, New York, N.Y. 10017, U.S.A.

PVC Pipelaying Group, The. *PVC Pipelaying Manual,* Her Majesty's Stationery Office, London, March 1967.

Reinhart, Frank W. "Recent Developments in Thermoplastic Piping," *Journal American Water Works Association,* Vol. 60, No. 12, pp. 1404-1410 (December 1968).

Reinhart, Frank W. "Engineering Properties of Plastics Applicable to Water Piping," *Journal American Water Works Association,* Vol. 59, No. 4, pp. 447-456 (April 1967).

Reinhart, Frank W. "Hydrostatic Strength and Design Stresses for Thermoplastic Pipe with Water," in *Simulated Service Testing in the Plastic Industry,* Special Technical Publication No. 375, American Society for Testing and Materials, Philadelphia, Pa., pp. 30-48 (1965).

Tiedeman, Walter D., and Milone, Nicholas A. *A Study of Plastic Pipe for Potable Water Supplies,* National Sanitation Foundation, School of Public Health, University of Michigan, Ann Arbor, Michigan, June 1955.

*ASTM 1248-65T Polyethylene Molding and Extrusion Materials

*ASTM 1784-65T Rigid Poly (Vinyl Chloride) and Poly-1, 2- Dichloroethylene Compounds

*ASTM 1788-62T Rigid Acrylonitrole-Butadiene-Styrene (ABS) Plastics

*ASTM 2235-67 Solvent Cement for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe and Fittings

*ASTM 2239-76 Polyethylene (PE) Plastic Pipe (SDR-PR)

*ASTM 2241-67 Poly (Vinyl Chloride) (PVC) Plastic Pipe (SDR-PR and Class T)

*ASTM 2282-66 Acrylonitrole-Butadiene-Styrene (ABS) Plastic Pipe (SDR-PR and Class T)

*ASTM 2564-67 Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Pipe and Fittings

*ASTM 2657-67 Heat Joining of Thermoplastic Pipe and Fittings

*ASTM 2774-69T Recommended Practice for Underground Installation of Thermoplastic Pressure Piping

*Available from American Society for Testing Materials, 1916 Race Street, Philadelphia, Pa. 19104, U.S.A.

*NSF Standard No. 14: Thermoplastic Materials, Pipe, Fittings, Valves, Traps, and Joining Materials (October 1965)

*NSF Standard No. 15: Thermoset Plastic Pipe, Fittings, Valves, Tanks, Appurtenances, Joining Materials and Thermoset Plastic Coatings for Use in Potable Water Systems

*Available from National Sanitation Foundation, School of Public Health, University of Michigan, Ann Arbor, Michigan

Those utilities using metric units might wish to review the ISO (International Organization for Standardization) recommendations on page C-8, Appendix C.

3. GENERAL

Information generally applicable to all plastics pressure pipes for water is given here with specific instructions for PE, PVC, and ABS plastics pipe presented under those headings.

3.01 Handling and Storing

Plastics pipe should be handled and stored in such a manner that it will not come in contact with materials that may damage or penetrate the plastic material. Such materials may produce deterioration of the pipe, reducing its hydrostatic pressure qualities or imparting taste and odor to water flowing through the pipe. The following materials, common to the building trades, may affect plastic pipe adversely:

Gasoline	Aromatic compounds
Lubricating oil	Synthetic paint solvents
Muriatic acid	Turpentine
Liquid or gaseous fuels	Paints
Acid solders	Hot water or steam

Plastic pipe damaged by such materials should be rejected.

Plastic pipes are made of strong though lightweight materials about one fifth the weight of steel or cast iron. As a result pipes made of this material are very easily handled and there is a tendency for them to be thrown about much more than their metal counterparts. This should be discouraged to prevent damage to the pipes.

Straight lengths of pipe should be given adequate support al all times. They should not be stacked in large piles, especially under warm temperature conditions, as the bottom pipes may distort, thus giving rise to difficulty in pipe alignment and jointing. When socketed and spigoted, pipes should be stacked in layers with sockets placed at alternate ends of the stack and with the sockets protruding, so as to avoid lop-sided stacks and the imparting of a permanent set to the pipes.

For long-term storage, pipe racks should preferably provide continuous support but, if this is not possible, then timber supports of at least 3 inches bearing width, at spacings not greater than 3 feet on centers should be placed beneath the pipes and, if the stacks are rectangular, at twice this spacing at the side. In such pipe racks, pipes may be stored not more than seven layers high, but if different classes of pipe are kept in the same racks then the thickest classes must always be at the bottom.

For temporary field storage where racks are not provided, care should be taken that the gound is level and free from loose stones. Pipes stored thus should not exceed three layers high and should be staked to prevent movement.

In tropical conditions stack heights should be reduced and pipes stored in the shade. In extreme conditions pipes may be stored under water. Stack heights should also be reduced if pipes are nested. (i.e. pipes stored inside pipes of larger diameter). Reduction in height should be proportional to the total weight of the nested pipes compared with the weight of pipes normally contained in such stowages.

Since the soundness of any joint depends on the condition of the spigot and the socket, special care should be taken in transit, handling and storage to avoid damage to these ends.

The impact strength of plastics pipe is reduced somewhat in cold weather, therefore rather more care in handling should be exercised in wintry conditions. At 40°F the reduction has become marked, particularly for PVC, and it should not be laid in such conditions.

When loading pipes on vehicles, care should be taken not to allow them to come into contact with any sharp corners such as loose nail heads or the like, as pipes may be damaged by being rubbed against these during transit.

While in transit, pipes should be well secured and supported over their entire length. For instance, pipes should not be allowed to wave about by being left projecting unsecured over the tailboard.

Pipes may be off-loaded from vehicles by rolling them gently down timbers, care being taken to ensure that pipes do not fall one upon another nor on to any hard or uneven surface.

Plastic pipe in coils should be stored with the coils laid flat with no pile in excess of 10 feet–less in tropical countries. Heavy material should not be stored on top of the pipe.

If, due to unsatisfactory storage or handling, a pipe is damaged or kinked, the damaged portion should be cut out completely.

3.02 Trench Preparation and Bedding

The trench should not be opened too far in advance of pipe laying, and should be backfilled as soon as possible. The trench bottom should be carefully examined for the presence of hard objects such as large stones, rocky projections, or large tree roots. In uniform, relatively soft, finegrained soils found to be free of such objects, and where the trench bottom can readily be brought to an even finish providing a uniform support for the pipes over their length, the pipes may normally be laid directly on the trench bottom. In other cases the trench should be cut correspondingly deeper and the pipes laid on a prepared underbedding, which may be taken from the excavated material if suitable.

Ideally the prepared underbed should consist of a free-running granular material passing a ¾-inch sieve; there should be insufficient fine particles or silt to prevent freedom of drainage or to interfere with its easy compactibility. Where the pipe is not under a road and is at a cover depth not exceeding 5 feet and where it will not be subjected to heavy surcharge loads, some departure from this requirement may be allowed, but the material should be selected to be free from large stones, boulders and other hard objects. A simple test to determine the suitability of soil for backfilling purposes is described in Par. 3.06.

The thickness of the prepared underbed should be at least 4 inches. It should be well compacted and brought to a level surface so as to provide uniform support for the pipe. Pipes should be laid directly on this bedding. Bricks or other hard material must not be placed under the pipe for temporary support.

Clay should never be used immediately around the pipe, for bedding, sidefill or backfill. It is not possible to compact it sufficiently and it is liable to swell, shrink and erode.

3.03 Pipelaying

The pipe should be positioned in the trench so as to avoid any induced stress due to deflection. For simi-rigid pipe, any deviation required should be obtained by using preformed pipe bends or, in the cases of small or slow directional changes, by the use of joints which are designed to allow deflection (e.g. certain types of rubber ring joints). Manufacturers' guidance should be sought before using joints for this purpose.

Pipes may, however, be joined at the trench side and, then placed into the trench, and the utmost care must be exercised during this operation to avoid straining pipes or joints. The pipes must be lowered by ropes into the trench, not dropped.

Solvent welded* pipelines should not be snaked into a trench less than one hour after jointing. In wintry conditions this time should at least be doubled. If rubber ring joints are used they should be checked after the pipe is positioned in the trench to ensure that they still fully engaged.

At all times during the handling and jointing of pipes, every effort should be made to prevent dirt or any foreign matter entering the pipe. If laying is stopped for a time the end of the last pipe should be blanked off temporarily.

3.04 Sidefilling

With flexible pipes it is of great importance that the sidefill should be firmly compacted between the sides of the pipe and the soil sides of the trench. Any trench sheeting should be partially withdrawn to allow this to be done. Before backfilling, any levelling pegs or temporary packing should be removed. After the pipes have been laid and tested, further bedding material should be placed around the pipe and be thoroughly compacted in 3-inch

*The term, "solvent cemented," is preferred by many authorities as more truly descriptive and less confusing.

layers by careful tamping up to the crown of the pipe, eliminating all cavities under the two lower quadrants of the pipe.

The same material should then be placed over the crown of the pipe for not less than two thirds of the diameter, with a minimum height of 4-inches, and thoroughly compacted. The process of filling and tamping should proceed equally on either side of the pipe, so as to maintain equal pressure on both sides.

3.05 Backfilling

Plastic pipes are able to carry the external loads imposed upon them in underground laying because, being able to deform to a considerable degree without fracture, they derive additional supporting strength from the lateral restraint afforded by the soil at the sides of the pipe which opposes any increase in the horizontal diameter of the pipe. This lateral support is of prime importance in enabling the pipe to carry the external loads without excessive deformation. It is therefore important when laying such pipes to take adequate precaution to ensure that, by satisfactory compaction of the backfill, the lateral support is effective. In designing pipelines of rigid plastic pipe, deflections up to 5 percent of the outside diameter of the pipes are permissible. Where it is foreseeable that pipe trenches may flood, then backfilling at least in part, should be carried out immediately after pipelaying, to prevent pipes floating out of position.

As with pipes of other materials it is necessary to ensure that sharp objects such as large stones do not bear directly upon them, and also that they are not placed where they may come into contact with them after the passage of time.

Where plastic pipes pass over other services and ground movement could cause these pipes to come into contact, a separator made of some non-abrasive material should be inserted between the two. A suitable separator would be a piece cut from the pipe itself.

It may be helpful, with thin-walled pipe, to fill it with water and lightly pressurize during the initial backfilling operation.

Normal filling of the trench should proceed in layers not exceeding 12 inches in thickness, each layer being well rammed. Heavy mechanical rammers should not be used until the fill has reached a depth of 12 inches above the top of the pipe.

Special consideration and selection of backfilling material will be necessary if the risk of surface subsidence is an important consideration, for example under roads.

3.06 Backfill Materials*

Soil Types

A soil is considered stable if it provides dependable support to the pipe and undergoes only slight volume change with variation in its moisture content. The ability of a soil to provide support depends upon its resistance to consolidation and its shear strength. In general, coarse grained soils are considered stable; in the Unified Soil Classification these are defined as soils

*Excerpted from ASTM Tentative Recommended Practice D-2774-69T of which 50 percent or less pass U.S. Standard No. 200 sieve. (The particle passing through No. 200 sieve is about the smallest size visible to the naked eye.)

Using the group symbols of the Unified Soil Classification (see below) the following are considered stable backfill: GW, GP, GM, GC, SW, SP, provided that maximum particle size is not greater than ½ inch.

It terms of over-all use, gravels with fines and sand are the best backfill materials for pressure pipe. Sand or gravel mixed with silts or clays, in which the sand or gravel constitute at least 50 percent of the mixture, are also suitable. Certain soils should not be used as backfill material; these include highly organic soils, identified by odor or spongy feel, and fat, highly plastic expansive clay. Frozen soil should not be placed in contact with the pipe.

Field Identification of Soils

Gravel - Minimum grain size ¼ inch.

Sand - Individual grains visible to the naked eye with maximum particle size about 0.25 inch. Fine sands display dilatancy and are nonplastic. (To test for dilatancy, place a pat of moist soil on the palm of the hand. If the soil displays dilatancy, water will appear at the surface of the pat on shaking and disappear when the pat is compressed by the fingers.)

Silt - Individual grains difficult to see with the naked eye. May be slightly plastic. Displays dilatancy. Easily washed from fingers. Low dry-strength.

Lean Clay - Individual grains difficult to see with the naked eye. Dry lumps have moderate to high strength. Can be rolled into a 1/8-inch thread having low to moderate strength. Does not display dilatancy.

Fat Clay - Shows no or very slow dilatancy and should not be used unless mixed with coarse grained material. Has high dry-strength. Has soapy feel and shiny streak results if fingernail is run over damp surface. Can be rolled into 1/8-inch threads having relatively high strength.

Unified Soil Classification—Group Symbols

GW Well-graded gravels, gravel-sand mixtures, little or no fines.
GP Poorly graded gravels, gravel-sand mixtures, little or no fines.
GM Silty gravels, poorly graded gravel-sand-silt mixtures.
GC Clayey gravels, poorly graded gravel-sand-clay mixtures.
SW Well-graded sands, gravelly sands, little or no fines.
SP Poorly graded sands, gravelly sands, little or no fines.
SM Silty sands, poorly graded sand-silt mixtures.

3.07 Mole-Plowing

The technique of laying pipes by mole-plow has been successfully applied to plastic pipe. This technique employs a modification of the drain-type mole-plow which is either pulled directly behind a tractor or, the tractor is anchored and pulls the plow towards it by means of a winch and cables. Pits are dug at directional changes, or closer, if long straight runs are to be installed, and the pipe is jointed on the day before installation, using the solvent weld technique for PVC pipe. Immediately behind the mole is an expander larger than the overall diameter of the joints on the pipe, and the leading end of the pipe to be installed is shackled to the back of the expander. The plow blade is lowered into one of the pits and the plow is pulled to the next pit, the pipe train being pulled in at the selected level until its leading end enters the second pit. The mole-hole should be kept as small as is consistent with the easy passage of the pipe.

The mole-plow technique eliminates trenching but, although it is quick and economically attractive, ground conditions could limit the laying of the pipes by this method. It is therefore essential to carry out a soil survey before deciding to use it and to establish carefully what other underground services pass through the area. Although plastic pipe has been widely laid by mole plowing in size ranges up to and including 6-inch nominal diameter with marked success, and although recent advances have enabled pipes of up to 10-inch diameter to be laid successfully by this method, it should be appreciated that mole plowing of large diameter pipe calls for expert knowledge, skill and equipment designed and used by specialist contractors.

3.08 Electrical Considerations

Being a non-conductive material, plastic pipelines cannot be located by electrical means. Where provision for detection by such methods is required, copper tracer cables may be buried in the pipe trench or wrapped around the pipe. Where plastic pipe replaces an existing pipe which has been used for electrical earthing a warning should be given to the electrical undertaking concerned.

3.09 Bracing and Thrust Blocking

Thrust blocking prevents the pipeline from moving when the pressure load is applied. In effect the thrust block transfers the load from the pipe to a wide load-bearing area of the solid trench wall. Thrust blocks are required at points where the pipe changes direction, e.g. tees, elbows, wyes, caps, valves, hydrants, and reducers. Thrust blocks should be constructed so that the bearing surface directly opposes the major force created by the pipe or fitting.

The size and type of thrust block depends on pipe size, line pressure, type of fitting, degree of bend and type of soil. For small pipe (2-inch diameter or less), a bearing area of one-half square foot is generally adequate and can be provided with lumber if properly braced. Bends in small-diameter pipe (2-inch or less) laid in long lengths or coils, particularly with solvent welded joints, may not require thrust blocking depending on local conditions (water pressures, soils, joints).

For 6-inch pipe, 4 to 5 square feet of bearing area is adequate except under unusual conditions (high pressures, poor soils). Blocks for larger pipe should be individually sized by the local engineer. An excellent reference is Smith, Wayne W., "How to Anchor Mains Against Thrust Forces," *Water Works Engineering*, pp. 96-100 (February 1963).

The recommended blocking for larger pipes (4 inches or more diameter) is 2,000 psi (compressive strength) concrete. One mix is one part cement, two parts washed sand, and five parts gravel. Water should be limited to that amount needed to wet the mix. Only rough forming is necessary.

When placing concrete on a plastic pipeline care should be taken to avoid encasing the pipe completely. This is because the slight flexibility of the plastic material may cause pulsing under pressure variation which will not harm the pipe within the concrete or clear of the concrete, but may cause a tendency for the pipe to shear at the interface between the concrete blocks and the backfill. A thin membrane (nonbitumized paper, thin roofing felt, or polyethylene film applied to a thickness of about 0.1 inch) should be placed between the concrete and the pipe.

3.10 Pressure Testing

The purpose of the pressure test is to establish beyond doubt that the pipe, joints, and fittings comprising the installation under test will satisfy local conditions. There is, therefore, no merit in testing at excessively high pressure which may serve only to blow gaskets, strain anchors and perhaps cause the failure of items which would have been perfectly satisfactory for the working conditions.

A variety of test specifications is in use, but for normal waterworks practice test pressures need not exceed twice the safe working pressure of the pipe.

At or below the maximum design pressure rating there shall be no objectionable surge or water hammer. To be objectionable there shall be either (1) continuing unsteady delivery of water, (2) damage to the piping system or (3) detrimental overflow from any control valves.

Where a pressure test is conducted on a pipeline jointed throughout with end-load bearing joints, e.g. spigot and socket solvent weld, it is not absolutely necessary to backfill the pipe before applying the pressure test, although it will probably be more convenient to do so. In any case, the joints themselves should not be covered until after the test has been applied, joints inspected and the test judged satisfactory.

Solvent welded pipelines should not be pressure-tested until at least 24 hours after the last solvent-welded joint has been made.

In the case of pipelines which are jointed with non-end-load bearing joints, e.g. rubber ring insertion type, each pipe length must be backfilled, except for the joint itself. This is also true of fittings such as valves which may be connected to the pipeline by a similar type of joint.

Where incomplete runs of pipe are to be tested, ends may be temporarily blanked off using, for example, flange adaptors and similar detachable couplings. It will be necessary for these to be braced against the very considerable thrust developed by test pressures. As an alternative method of blanking off, a flange may be solvent welded to the pipe end. This may be conveniently accomplished where a flanged fitting e.g. a valve, is subsequently to be inserted in the line. For bracing or thrust blocking, it will normally be necessary to cut a short trench at right angles to the pipe trench and to insert railway sleepers or other strong bracing. It may also be necessary to strut the pipe to prevent vertical or lateral movement if the pipe end is more than 2 feet clear of the compacted backfill. In no circumstances should a blanked-off end be bracing against the end of another pipe in the line. The practice of pressure testing against closed valves is to be discouraged unless the valves are known to be suitable for pressure testing.

If a pressure test is carried out on a pipeline not completely filled with water, surge pressures of sufficient magnitude to cause bursts may be set up (an explosion hazard may exist, see Section 5.04). Therefore all air should be purged from the line, and this may be done through air bleed valves placed at the highest points. It is also desirable to fill lines from their lowest point, and in any case, a foam plastic pig forced through the line under the pressure of the incoming water will force out air from the line.

If it is suspected during the early stages of a pressure test that the pipeline has not been completely filled with water, then the test must be discontinued and steps taken to purge the line.

As in the case of test pressures, there is also a number of accepted specifications for applying a pressure test to pipelines. One in common use is filling the pipe with water, taking care to evacuate any entrapped air and slowly raising the system to the appropriate test pressure. From a timing point of view, the test has now started.

After the specified test time has elapsed, usually one hour, a measured quantity of water is pumped into the line to bring it to the original test pressure, if there has been a loss of pressure during the test. The pipe shall be judged to have passed the test satisfactorily if the quantity of water required to restore the test pressure does not exceed the amount calculated by the formula: 1 gallon per mile of pipe, per inch of nominal diameter, per 100 feet head of test pressure per 24 hours.

Because of its slightly elastic nature, plastic pipe under prolonged test pressure may tend to expand, slightly but sufficiently to give a fall in the pressure reading, thus giving the false impression that there has been a loss of water. Similarly, reference has been made to the high thermal expansion and contraction of plastic pipe. Therefore, if prolonged pressure tests are conducted on exposed pipes in widely varying ambient temperatures, the temperature change will cause fluctuation of the pressure, e.g. temperature drop, increase in pressure and vice versa.

Variations of this type will be much more marked in the case of exposed pipes under free end conditions, than in the case of backfilled pipes. Nevertheless, one or both of these conditions will probably apply to some extent to nearly all pressure tests. For this reason, testing periods should not be prolonged.

Where leaks are discovered they should be repaired promptly and the line retested.

Drain, waste, vent and other non-pressure piping: All openings should be closed and the system subjected to an internal pressure (either water or air) of 5 psi, held for 15 minutes, and then inspected while still under pressure. If any leaks or other defects are found, they should be corrected and a retest made.

3.11 Disinfecting Water Mains

See "AWWA Standard for Disinfecting Water Mains," *AWWA C601-68,* American Water Works Association, Inc., 2 Park Avenue, New York, N.Y. 10016, U.S.A. Also published in September 1968 issue of *Journal AWWA.*

An explosion hazard may exist during disinfection procedures (see Section 5.04).

3.12 Tolerances

Satisfactory installation and performance of all pipe requires a certain dimensional uniformity. U.S. practice is shown in Table H-1 below:

Table H-1: Manufacturing Tolerance Ranges for Plastic Pipe

	ABS		PE		PVC	
Measurement	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
Out-of roundness (in.)	±0.008	±0.75				
Wall thickness	0.10	0.606	0.06	0.404	0.06	0.75
Tolerance (in.)	±0.020	±0.73	±0.020	±0.048	+0.02	+0.09
Inside diameter (in.)			0.622	6.065		
Tolerance (in.)			-0.035	+0.020		
Outside diameter (in.)					0.405	12.75
Tolerance (in.)					±0.008	+0.075

A tolerance of ± 1 inch is allowed in pipe lengths of ABS and PVC pipe.

3.13 Pressure Drop

The pressure drop or head loss is commonly calculated using a Hazen-Williams coefficient (C) of 150. Nomographs for rapid determination of pressure drop or head loss for various flows and pipe diameters are in widespread use, *but* the user of plastics pipe is warned that the nominal diameters shown on charts may differ significantly from the actual diameter of plastics pipe. A few examples for PVC pipe from Commercial Standard CS256-63: A nominal ½-inch (0.500″) pipe may have an average inside diameter (ID) ranging from 0.716″ to 0.800″ depending on its pressure rating, material specification, and whether threaded or not. Similarly the ID of a 1-inch pipe may vary from 1.195″ to 1.263″; a 12-inch pipe from 12.352″ to 12.676″.

The significant difference in hydraulic capacity between the nominal and actual diameters is obvious. Therefore when calculating head losses, the actual average diameter should be determined. Many manufacturers have published Hazen-Williams tables or charts for their own pipe products. An example is shown in Figure H-1.

3.14 Pressure Rating

Plastic Pipe is pressure-rated at a standard temperature of 73.4°F. Although pressure resistance decreases with temperature rise, temperature is not critical for water pipe in buried applications because most water temperatures run below 73.4°F. The only critical time for temperature considerations is during installation.

The pressure rating (PR or P) is the estimated maximum operating internal water pressure (psi) at which the pipe can function without failure.

To provide a basis for a constant pressure rating over all sizes the industry has adopted the standard dimension ratio-pressure rated (SDR-PR) system.

The standard dimension ratio is the ratio of pipe diameter to minimum wall thickness (t, inches). In the case of ABS and PVC pipe, the outside pipe diameter (OD, inches) is used; for PE pipe, the inside pipe diameter (ID, inches) is used.

The relation between SDR, hydrostatic design stress (S, psi), and pressure rating is given by the equations:

for ABS and PVC pipe:

$$\frac{2S}{P} = SDR - 1 \quad \text{or} \quad \frac{2S}{P} = \frac{OD}{t} - 1$$

for PE pipe:

$$\frac{2S}{P} = SDR - 1 \quad \text{or} \quad \frac{2S}{P} = \frac{ID}{t} - 1$$

These are commonly known as the ISO equations. Pressure ratings for various SDR's and pipe materials appear in the ASTM standards previously cited.

PRESSURE DROP CHART

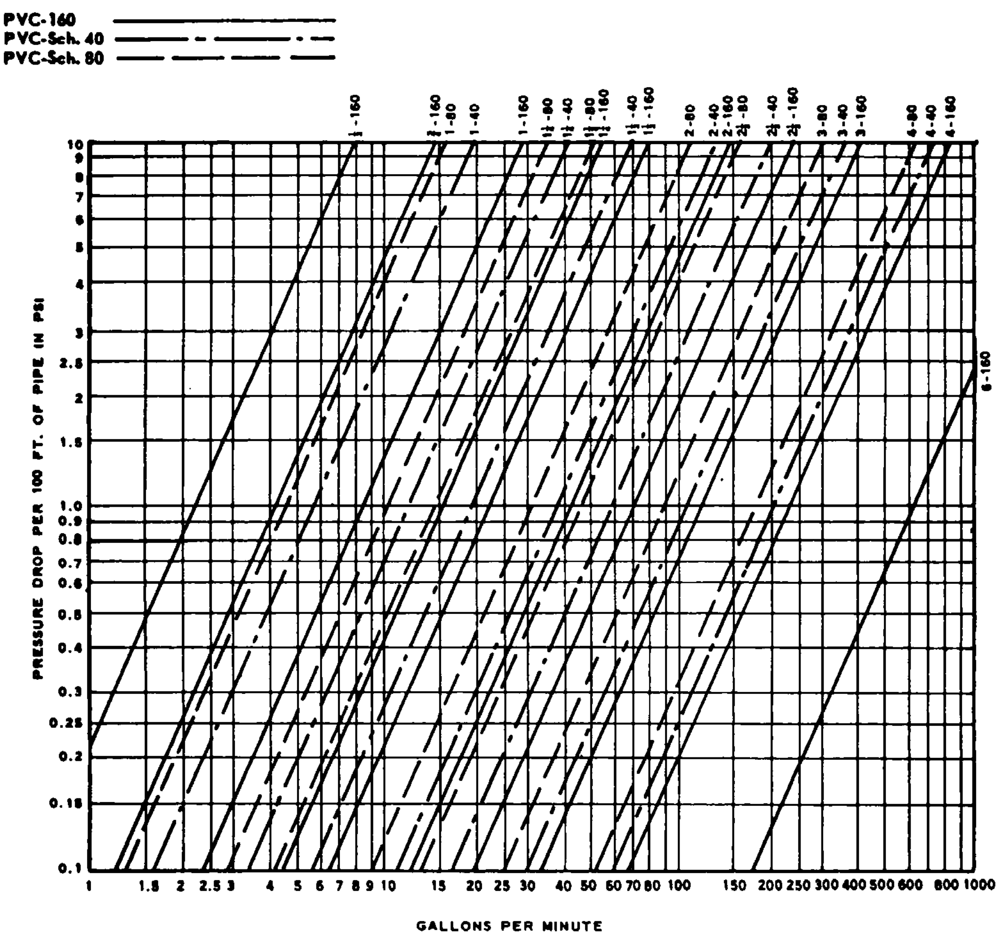

Figure H-1: TYPICAL HEAD LOSS CHART FOR PLASTIC PIPE

4. INSTALLATION OF POLYETHYLENE (PE) PLASTIC PIPE

4.01 Properties

Among the properties of polyethylene which make it an excellent pipe material are its flexibility, its high strength to weight ratio, and its chemical inertness. As a result, polyethylene pipe is lightweight, coilable, and quite resistant to corrosive environments. The pipe can be joined by fusion techniques, and by mechanical insert or compression fittings. Polyethylene's low temperature properties and toughness make the pipe resistant to rupture from mechanical shock, freeze-thaw conditions, and abrupt changes in operating pressures.

Some properties of polyethylene may detract from its fully satisfactory service as pipe unless the user and contractor consider them properly. Because of its flexibility and low surface hardness, proper support and burial of the pipe to minimize sag or cutting by sharp objects is essential. Its relatively low softening point makes it necessary to avoid installation and service at high temperatures. Polyethylene is not a conductor of electricity, so it cannot serve as an electrical ground.

Polyethylene is a ductile material which can resist considerable bending stresses without damage. However, kinking of the pipe during installation must be avoided. As a general rule, polyethylene pipe can be bent to a radius of curvature about ten times the outside diameter of the pipe. During installation of coiled pipe, the pipe should be uncoiled and laid to follow its natural curvature.

Since polyethylene is thermoplastic, its stiffness and tensile properties depend on the temperature. At low temperatures, polyethylene pipe is more difficult to uncoil and install than at higher temperatures. Its design pressure ratings also depend on temperature, and unless otherwise specified, apply to 73°F. Polyethylene pipe can generally be used for continuous service at temperatures between -40 and 120°F. Specific information should be obtained from the manufacturer.

Polyethylene is classified as "slow burning" under ASTM Procedure D-635. Because it tends to soften at elevated temperatures, exposure in unusually warm locations, near steam pipes or near furnaces should be avoided.

Polyethylene pipe has excellent chemical resistance to most organic solvents, aqueous salt solutions, mineral acids, and alkalis. Some hydrocarbons are absorbed by polyethylene and cause swelling and some loss of strength, but the properties are largely restored when the hydrocarbons are allowed to evaporate from the pipe. The low density polyethylene (Type I) may also swell in oils and greases, but the medium (Type II) and high (Type III) density resins used in pipe are more resistant to these materials. Polyethylene is virtually unaffected by water and absorbs only 0.005% by weight in a 24-hour immersion test.

Polyethylenes are sometimes subject to a type of chemical attack called "stress cracking". Stress cracks develop in polyethylene when the material is stressed (bent, twisted, cut, etc.) and then exposed to some chemical environments. The rate and degree of attack is a function of the stress level and the chemical environment and is specific for each combination. For this reason, it is recommended that unusual applications be investigated, either by tests or by inquiry of those experienced in the use of polyethylene in chemical piping, or both.

Polyethylene pipe resists attack by termites, fungi, insects, or other biological agents when buried in soil. Rodents will sometimes gnaw on buried plastic pipe to get at food or water. Also, if the soil around the pipe is loose and therefore easy for the rodent to burrow in, the pipe may be gnawed if it is in the way. Rodent repellents may be effective in preventing damage of this type.

4.02 Handling and Storing

Polyethylene without stabilizers has a limited life outdoors in direct sunlight due to the deterioration caused by the ultra-violet rays of the sun. Polyethylene pipe usually is manufactured with a stabilizer system that protects it from harmful radiation. If the pipe is to be used in above-ground service for extended periods, it should be stabilized with suitable additives, one of which is carbon black. At ambient temperatures and protected from direct sunlight, polyethylene has an indefinite storage life. Polyethylene should be protected from prolonged exposure to elevated temperatures and from direct sunlight. Non-weather resistant polyethylene pipe, however, must be stored under cover and protected from direct sunlight.

Coils may be stored either on edge or stacked flat one on top of the other, but in either case they should not be allowed to come into contact with hot water or steam pipes and should be kept away from hot surfaces. Coils of large diameter (1-½ inch up) should not be stored on edge in hot weather or direct sun.

Straight lengths should be stored on horizontal racks giving continuous support to prevent the pipe taking on a permanent set.

Polyethylene is a tough resilient material which may be handled easily. However, because it is softer than metals it is more prone to damage by abrasion and by objects with a cutting edge. Such practices as dragging coils over rough ground should therefore be avoided.

If, due to unsatisfactory storage or handling, a pipe is damaged or 'kinked', the damaged portion should be cut out completely.

The material is not affected by low temperatures as much as are some other plastics materials, and there is no need for more cautious handling during cold weather.

4.03 Installing

The pipe is supplied in coils or straight lengths. When pipe is cut from a coil it should be mounted to minimize stresses in installation. In no case should the pipe be subjected to reverse curvature.

Polyethylene plastic pipe may be cut to length with either a handsaw or knife. The pipe should be snaked in the ditch to allow for expansion and contraction; for each 10°F temperature change anticipated, an allowance of 1 inch per 100 feet of pipe installed should be made. In a typical temperature climate with the pipe buried below the frost line and summer ground temperatures of 60°F, the temperature range would be from 40 to 60°F, or 20°F variation. Thus for each 100 feet of pipe installed at the summer temperature, at least an additional 2″ of pipe would be laid by snaking the pipe from side to side in the ditch. If the pipe is being installed at a lower temperature, less additional pipe would be necessary. The slack should be introduced uniformly along the length of the pipe run. In short runs, changes in direction of the pipelines will often give sufficient allowance for expansion and contraction stresses.

The minimum burial depth for installations of polyethylene pipe is 12 to 18 inches. When crossing under roads which are not self-supporting a steel or concrete conduit to prevent collapse due to the continual packing action of moving vehicles is necessary. In areas where ground frost penetrations occur the polyethylene plastic pipe should be buried at least 12 inches below typical ground frost penetration. If frost penetrations are erratic the pipe should be buried 4 inches below the maximum recorded frost penetration. Maximum burial depth should not exceed 7.7 feet for 75-pound pipe and 12.7 feet for 100-pound pipe.

Polyethylene pipe may be cold bent without injury to a radius equal to that of the inside wraps of the coil in which it was shipped. These radii are as follows:

1/2″ pipe------------7-1/2″ radius
3/4″ pipe------------10″ radius
1″ pipe------------10″ radius
1-1/4″ pipe------------12″ radius
1-1/2″ pipe------------16″ radius
2″ pipe------------20″ radius

Elbows should be used for sharp bends.

When polyethylene pipe is installed above ground or in buildings, plastic pipe hangers may be used to support the pipe. Care should be taken not to overtighten and cause the hanger clamps to cut into the pipe. Pipe hangers should be correctly aligned and should provide a flat smooth surface for contact with the pipe. Supports having sharp edges should be avoided. All types of manual controls, and valves in particular, should be firmly anchored so as to prevent imparting any turning movement to the pipe by operation of the valve control.

Polyethylene pipe should not be installed in contact with or close to hot surfaces.

When not supported continuously in horizontal runs hangers and brackets should be used at approximately the spacings given in Table H-2.

4.04 Joining

Polyethylene (PE) pipe (or tubing) can be joined to other PE pipe or fittings or to pipe or appurtenances of other materials by selecting one or more of the following joining systems. (Further information and specific procedures may be obtained from the pipe manufacturer.) PE pipe cannot be joined by solvent welding or by the use of threaded fittings.

Insert fittings are available for PE pipe (not for tubing sizes) in plastics or metallic materials and in a variety of styles—couplings, tees, ells, adapters. Pressure ratings for pipe and fittings should be the same. Insert fittings place a restriction in the line which increases head loss, consequently delivering a

Table H-2. Support Centers for Horizontal Polyethylene Pipes*

Nominal Size	PE 1404		PE 2305, 2306, 3306		Nominal Size	PE 1404		PE 2305, 2306, 3306	
Inches	Foot	Inch	Foot	Inch	Inch	Foot	Inch	Foot	Inch
1/4	1	0	1	6	2 1/2	1	9	2	9
3/8	1	0	1	6	3	2	0	3	0
1/2	1	3	2	0	4	2	3	3	6
3/4	1	3	2	0	6	2	9	4	3
1	1	3	2	0	8	3	6	5	3
1 1/4	1	6	2	3	10	4	3	6	6
1 1/2	1	6	2	3	12	5	0	7	6
2	1	9	2	9	-	-	-	-	-

*For water at 70F. For temperature above 70F closer supports are required. At 100F and above continuous support is necessary. These support spacings apply to pipe with water pressure ratings of 80 psi or more.

smaller quantity of water. Where low pressures obtain in a water system or where high delivery of water is required this method is not recommended.

For attaching plastic lines to metallic systems, it is recommended that an insert adapter be used. This is attached to the plastic pipe in the same manner as other plastic insert fittings. Threaded end only of the adapter is coated with a plastic joint compound and tightened into the female connections. *Do not use joint compound on the plastic pipe itself.*

The pipe should be cut square using a hacksaw or knife and deburred. Two all stainless steel clamps are slipped over the end of the pipe. The end of the pipe is forced over the barbs of the fitting until it makes contact with the shoulder of the fittings. (The end of the pipe may be softened by immersing in hot water to permit the pipe to slip on more easily. *Under no circumstances should pipe dope, gasket cement, detergents, or petroleum lubricants be used.)* The clamps are then tightened to provide a leakproof connection. Care should be taken to see that the clamp screw positions are offset.

Flared fittings are available. Standard AWWA stops, fittings and coupling nuts commonly used with copper tubing may be used by heat flaring the plastic pipe with a simple flaring tool.

A moderate amount of heat is required for flaring operations. Heating should be carefully controlled to avoid uneven heating or over-heating. Heating beyond the point of softening, when making flares may result in changes of dimension and may cause permanent damage, although PE material does not appear to be as adversely affected as ABS or PVC.

One manufacturer gives the following instructions for installation of PE pipe with the compression-flare system:

Use with 1" Flare-Tube and 3/4" AWWA Copper outlet stops and fittings - requires special nut.

1. First use a tube cutter to get a square end on the pipe. Then slip the compression nut over pipe and heat pipe with torch, concentrating on top 1/2-inch of pipe. If pipe smokes or flames, flame is too close, or not moving fast enough around pipe. Heat only outside.

2. The glossy pipe will first mist. Then it will appear glossy again, and will flare out around the edge. When the gloss reappears, feel inside the pipe until the upper edge is flexible (an indentation can be made with a fingernail). Apply heat once more around the pipe.

3. Pull nut up so that the top of the pipe is even with the upper edge of the bottom thread of the nut. Then bring the compression clamp into place and lock the clamp. Note that a shoulder in the clamp allows both nut and pipe to be locked.

4. Now turn compression flare tool into nut. Make it hand tight. Then insert the wrench and make the flare wrench tight. Extra muscle is not required. As soon as it is wrench tight, wait five seconds, then unscrew compression flare.

Compression fittings are available for both PE pipe and for PE tubing.

Joints can be made either pipe end to pipe end or pipe end to socket fitting by a *heat fusion method.* This method involves heating the surfaces to be joined to a temperature that will permit fusion of the surfaces when brought into intimate contact. Special tools are required for this method and the procedure is outlined in ASTM D2657-67. Care should be taken to insure the compatibility of the PE plastics in the pipe and fittings.

4.05 Jet Pump Water Wells

Flexible polyethylene pipe may be used for single and two-pipe jet well installations. It is also recommended as a suction pipe for wells of less than 25 feet in depth. For this purpose 75 psi or Series 2 pipe should be employed. It is recommended that polyethylene pipe be used down to depths as indicated in Table H-3 for the appropriate cutoff pressure of the system. It should not be used for deep well turbine installations.

Table H-3

Maximum Depth Settings for Jet and Submersible Pump Well Installations (73°F) Using Polyethylene Pipe

Pressure Rating of Pipe, psi	At Shut-Off Pressure of 30 psi	40 psi	50 psi	60 psi
	Feet	Feet	Feet	Feet
80	116	93	69	--
100	162	139	115	92
125	219	196	173	150
160	300	277	254	231

4.06 Submersible Pump Installations

For submersible pump installations, these general instructions should be followed:

a. Use brass adapters at both the well seal and the pump outlet.
b. Double clamp both joints, using all stainless steel clamps.
c. Use snubbers at the pump, at the static water level, and at about half-way between to avoid abrasion of the pump housing, the pipe or the power cable against the casing.
d. Tape the power cable to the pipe about every 5 feet.
e. Attach a stainless steel cable (1000 lb. test) to the well seal and to the pump adapter; this prevents loss of pump and will assist in raising the pump in case of pump failure.

5. INSTALLING POLYVINYL CHLORIDE (PVC) PLASTIC PIPE

5.01 Properties

Most polyvinyl chloride pipe is made of rigid unplasticized PVC, gray in color and has a maximum operating temperature of approximately 150°F. PVC has a relatively high tensile strength and modulus of elasticity and is, therefore, more rigid and stronger than most thermoplastics. It is chemically resistant to many corrosive fluids but may be damaged by ketones, aromatics, and chlorinated hydrocarbons. It can be used for all types of water, including highly chlorinated water.

PVC is subject to abrasion and is notch-sensitive in thin-wall pipe. In heavy-wall pipe, such as Schedule 80 or Class T, notches or scratches, unless quite deep, are not significant. Even in heavy-wall pipe however, notches become significant if the pipe is pressured to a point near its rated capacity.

For pressure purposes, PVC has the highest design stress value of any plastic material available for tubing and pipe.

PVC pipe material comes in three types. Type I pipe material, sometimes called rigid PVC, contains no plasticizer and a minimum amount of compounding ingredients, so that it is the closest to base PVC resin. This group of PVC plastic has a hydrostatic design stress *(not* the design service stress*) for water at 73°F of 2000 psi. They are useful up to 140°F. The hydrostatic design stress for water is probably 1600 psi at 100°F.

Type II PVC plastics, sometimes called high-impact or modified PVC plastics, cover a very wide range of materials with hydrostatic design stresses of 1000, 1250, 1600 and 2000 psi for water at 73°F. The 1000 psi material has high impact strength and is much more flexible than Type I. Type II PVC pipe materials consist of PVC resin plasticized by rubbers or elastomers and other compounding materials. A wide range of products is obtained by varying the amount and kind of rubber or plasticizer as well as the base PVC resin.

Type IV PVC is modified Type I. Its base resin has a higher chlorine content. It has a hydrostatic design stress of 1600 psi for water at 73°F and is

*The design service stress is the product of the hydrostatic design stress and the service factor. The service factor is specific for a specific medium at a specific temperature.

useful up to 180°F under pressure. Formerly known as PVDC it is now called PVC 4116.

Within each type there are several grades. Types and grades do not refer to quality but to ASTM classification systems as given in their standards. Selection of type and grade is based on application.

5.02 Handling and Storing

See Par. 3.01.

5.03 Installing

Pipes installed underground are not normally subjected to a large temperature variation and in such cases when positive joints are used, the temperature movement can usually be taken up as elastic strain in the pipe. Linear expansion of PVC in practice may be taken as 7½ inches per 100 feet length per 10°F change. For a 10°F temperature variation using solvent weld joints on buried pipelines, a stress of about 85 Lbf/in^2 will be developed longitudinally in the pipe. This is about one-sixth of the long-term circumferential stress of the material and may safely be ignored. There may be an exceptionally large change of temperature immediately after backfilling or on filling the pipe with liquid as, for example, when work is being carried out in hot sunshine. Trouble from this may be minimized by deferring final connection at any fixed point until the majority of the line has been covered with backfill.

For exposed piping, considerations for expansion and contraction must be given, especially in long runs or where a pronounced temperature variation is to be encountered. In such installations the pipe in overhead installations must be permitted to float in the hangers and its lateral movement must not be confined. In supporting an overhead or elevated PVC line the following spacing between supports should be observed:

Table H-4. Support of Elevated PVC Pipe

Pipe Size	Supports on Centers
1/2" through 1"	4 ft.
1 1/4" through 2"	5 ft.
2 1/2" through 6"	6 ft.

Where temperatures exceed 130°F continuous support is recommended.

Although PVC pipe is impervious to ultraviolet light and general weather conditions, outdoor installations should be buried to prevent physical and mechanical damage. PVC pipe, filled with water, will not withstand repeated freeze-thaw cycling, thus, earth cover or thermal protection must be provided in freezing climates.

5.04 Joining

The most commonly used line joints on unplasticized PVC are the solvent weld joint, using a pre-formed socket on the pipe; and the push-on joints of the rubber ring type using either a socket integral with the pipe, or of the loose collar type with two rubber rings.

There are two basic systems of pipe end preparation for *solvent welded joints.*

In the *Taper/Taper System,* both the spigot and the socket of the pipes are shaped, the former in a taper and the latter in a bellmouth. The included angle of the taper is often 2 degrees.

The *Taper/Parallel System* requires the shaping of the pipe at one end only. This end is formed to a socket which is tapered and included angles of 1/2 degree to 1 degree are usual. The spigots in this system are unshaped, that is, they are the parallel body of the pipe itself.

Joints made with the above-systems are fully end-load bearing.

The solvent cement used with any given pipe-joint system should be the one recommended by the manufacturer of the pipe and fittings being used, and his instructions should be closely followed.

Since solvent cement is aggressive to PVC, care must be taken to avoid applying excessive cement to the inside of the pipe socket, as any surplus cannot be wiped off after jointing. Surplus cement should be cleaned off all joints after making, and spillage of cement on the ground, and especially on to pipe or into the trench should be avoided as far as possible and in any case cleaned up immediately.

Empty cement tins, brushes, rags or papers impregnated with cement should not be buried in the trench. These should be gathered up, not left scattered about, as they are a hazard to animals which may chew them.

The following material is quoted from Plastics Pipe Institute Technical Report PPI-TR10 (Feb. 1969):

Recommended Practice for Making
Solvent Cemented Joints with Polyvinyl Chloride
Plastic (PVC) Pipe and Fittings

Scope

A procedure is described for making joints with polyvinyl chloride plastic (PVC) pipes, both plain ends and fittings, and bell ends, by means of solvent cements, sometimes called solvent welding. These procedures are general ones for PVC piping. Manufacturers should supply additional specific detailed instructions for their particular products, if and when it seems necessary.

The techniques covered are applicable only to PVC pipe, both plain and bell-end, and fittings of the same type and grade as described in Specification for Rigid Polyvinyl Chloride Compounds (ASTM Designation: D1784-68).

Pipe and fittings are manufactured within certain tolerances to provide for the small variations in the extrusion, belling and molding processes and not to exact size. A partial list of standards for PVC pipe, fittings and cements suitable for use in making solvent cemented joints is given in Appendix C.

Significance

The techniques described herein can be used to produce strong pressure-tight joints between PVC pipe and fittings, either in shop operations or in the field. However, skill and knowledge on the part of the operator are required to obtain a good quality joint. This skill and knowledge can be obtained by making joints under the guidance of skilled operators and testing them until good quality joints are obtained.

Materials

Pipe and Fittings. - The pipe and fittings should meet the requirements of current applicable PVC piping standards. A list of these standards is given in Appendix C.

Solvent Cement -

Definition. - A solvent cement is an adhesive made by dissolving the plastic in suitable solvent or mixture of solvents. The solvent cement dissolves the surfaces of the coated pipes and fittings to form a continuous bond between the mating surfaces so that the joined parts become essentially one, provided the proper cement is used for the particular materials and proper techniques are followed.

Specification. - The solvent cement should meet all the requirements of ASTM Specification for Solvent Cement for Polyvinyl Chloride (PVC) Plastic Pipe and Fittings. ASTM Designation: D2564-67.

Selection. - PVC solvent cements are available in two general viscosity categories, namely, light and standard, the first having a lower viscosity than the second. The light cements are intended for use with pipes and fittings up through 2-inch in nominal size and for pipes and fittings where interference fits between the parts to be joined occurs. Light cements exhibit a wet film thickness of less than 0.012 inch when measured with a Nordson Wet Film Thickness Gage or equivalent (Note 1). Standard cements, although primarily intended for use with pipes and fittings over 2-inch in nominal size and for pipe and fittings where gaps between the parts to be joined occurs, are also satisfactory for use with smaller sizes. The gap may be as large as 0.020 inch on a side. Standard cements exhibit a wet film thickness of 0.012 to 0.036 inch when measured with a Nordson Wet Film Thickness Gage or equivalent. (Note 1.) The procedure supplied with the gage shall be followed in making these determinations.

Storage. - PVC solvent cements should be stored in a cool place except when actually in use at the job site. These cements have a limited shelf life when not stored in hermetically sealed containers. Screw top containers are not considered to be hermetically sealed. Consult the cement manufacturer for specific storage recommendations on storage conditions and shelf life.

The cement is unsuitable for use on the job if it exhibits an appreciable change from the original viscosity, or if a sign of gelation is apparent. Restoration of the original viscosity or removal of gelation by adding solvents or thinners is not recommended.

Note 1. Available from Nordson Corp., Amherst, Ohio, as Nordson No. WFG-100B. To use this gage, dip a short length of 1-inch pipe vertically into the cement at a temperature of approximately 23°C (73°F) to a depth of 1.5 to 2 inches for a period of 15 secbnds. Remove the pipe from the cement and hold the pipe horizontally for 45 seconds. Measure the wet film thickness on the top surface of the pipe with the end of the gage about ¼-inch form the end of the pipe. With a little care and experience the wet cement layer can be readily measured to ∓0.002 inch.

Cleaners. - Cleaners, sometimes called primers, are of two types, chemicals and mechanical (abrasives).

Chemical Cleaners. - The chemical cleaners are as follows:

a. Methyl ethyl ketone (MEK)
b. Methyl isobutyl ketone (MIBK)
c. Tetrahydrofurane (THF)
d. Cyclohexanone
e. Dimethyl formamide (DMF) mixed with THF
f. Cyclohexanone mixed with DMF
g. Acetone

Mechanical Cleaners. - The mechanical cleaners are as follows:

a. Fine abrasive paper or cloth (180 grit or finer)
b. Clean, oil-free, steel wool

Procedure

Cutting the Pipe. - Pipe is cut square with the axis, using a fine tooth hand saw and a miter box, or a fine toothed power saw with a suitable guide. Wood working blades may be used. A rotary cutter may be used if the cutting blades are specifically designed for cutting plastic pipe in such a way as not to raise a burr or ridge (flare) at the cut end of the pipe. If other tools are not available, a standard rotary metal pipe cutter may be used, provided great care is taken to remove all of the ridge raised at the pipe end by the wedging action of the cutting wheels. Failure to remove the ridge will result in the cement in the fitting socket being scraped from the socket surface, producing a dry joint with a high probability of joint failure. All burrs are to be removed with a knife, file or abrasive paper.

Test Fit the Joint. - Wipe both the outside of the pipe and the socket of the fittings with a clean, dry cloth to remove foreign matter Mate the two parts without forcing. Measure and mark to indicate when the socket depth of the fitting on the outside of the pipe (do not scratch or damage pipe surface) to indicate when the pipe end will be bottomed. The pipe should enter the fitting, especially on sizes 3-inch and larger, at least 1/3 of the socket depth. If the pipe will not enter the socket by that amount, the diameter may be reduced by sanding or filing. Extreme care should be taken not to gouge or flatten the pipe end when reducing the diameter.

Joint Preparation. - Surfaces to be joined should be clean and free of moisture before application of the cement. The outside surface of the pipe (for the socket depth) and the mating socket surface shall be cleaned and the gloss removed with one of the chemical cleaners listed in paragraph 1 above applied with a clean, dry cloth. An equally acceptable substitute is to remove the gloss from the mating surfaces (both pipe and socket) with abrasive paper or steel wool). Wipe off all particles of abrasive and/or PVC before applying the cement.

Application of Cement -

Handling Cement. - Keep cement can closed and in a shady place when not actually in use. *Discard* the cement when an appreciable change in viscosity takes place, or at the first sign of gelation. The cement should not be thinned. Keep brush immersed in cement between applications. Note: A gel condition is indicated when the cement does not flow freely from the brush or when the cement appears limpy and stringy.

Brush Size. - The cement is applied with a natural bristle or nylon brush, using 1/2-inch brush for nominal pipe sizes 1/2-inch and less, 1-inch wide brush for pipe up through 2-inch nominal pipe size, and brush width at least 1/2 of nominal pipe size for sizes above 2-inch except that for pipe sizes 6-inch and larger a 2 1/2-inch brush is adequate.

Application of Cement. - PVC solvent cement is fast drying and therefore the cement shall be applied as quickly as possible, consistent with good workmanship. It may be necessary for two workers to perform this operation for larger sizes of pipe. Under conditions of high atmospheric humidity, quick application is important to minimize condensation of moisture from the air on the cement surface. The surface temperature of the mating surfaces should not exceed 110°F at the time of assembly. In ambient temperatures above 110°F, or in direct sunlight on hot days, the pipe temperature may be reduced by swabbing the surfaces to be cemented with clean wet rags provided all water is removed before the cement is applied. First, apply a full even coat of cement to the pipe surface, to the depth of the fitting socket. Next, apply a uniform, thin coating of cement to the interior of the fitting socket, including the shoulder at the socket bottom. Recoat the pipe with a second uniform coat of cement, including the cut end of the pipe.

Special Instructions for Bell End Pipe. - The preceding procedure may be followed in the case of bell end pipe except that great care should be taken not to apply an excess of cement in the bell socket, nor should any cement be applied on the bell-to-pipe transition area. This precaution is particularly important for installation of bell end pipe with a wall thickness of less than 1/8 inch.

Assembly of Joint. - *Immediately* after applying the last coat of cement to the pipe, insert the pipe into the fitting until it bottoms at the fitting shoulder. Turn the pipe or fitting 1/4 turn during assembly (but not after the pipe is bottomed) to evenly distribute the cement. Assembly should be completed within 20 seconds after the last application of cement. The pipe should be inserted with a steady even motion. Hammer blows should not be used. If there is any sign of drying of the cement surfaces, due to delay in assembly, the surfaces should be recoated, taking care again not to apply a surplus of cement to the inside of the socket, particularly in bell end pipe. As large axial forces are necessary for the assembly of interference fit joints in large size pipe, two or more men are needed for such joints. Mechanical forcing equipment - "Come-alongs", or levers and braces may also be necessary. Until the cement is set in the joint, the pipe may back out of the fitting socket if not held in place for approximately one minute after assembly. Care should be taken during assembly not to disturb or apply any forces to joints previously made. Fresh joints can be destroyed by early rough handling. After assembly, wipe excess cement from the pipe at the end of the fitting socket. A properly made joint will normally show a bead around its entire perimeter. Any gaps at this point may indicate a defective assembly job, due to insufficient cement, or use of light bodied cement on a gap fit where heavy bodied cement should have been used.

Set Time. - Handle the newly assembled joints carefully until the cement has gone through the set period. Recommended set time is related to temperature as follows:

30 minutes minimum at 60° to 100°F
1 hour minimum at 40°F to 60°F
2 hours minimum at 20°F to 40°F
4 hours minimum at 0°F to 20°F

After the set period, the pipe can be carefully placed in prepared ditch and snaked from side to side. Prior to backfilling, the pipe shall be brought to approximate operating temperature by either shade backfilling, or by filling with water, or by allowing to stand overnight. The pipe system should be allowed to stand vented to the atmosphere prior to pressure testing. The set period before the system is pressure tested will depend on the specific cement, the size of the pipe, the ambient temperature, and the dry-joint tightness. Necessary cure time can vary from minutes to days depending on conditions and the solvent cement used. Table H-5 shows cure schedules for several ranges of pipe sizes and temperatures. As a general rule, relatively short cure periods are satisfactory for high-ambient temperatures with low humidity, small pipe sizes, quick-drying cements, loose joints, and relatively high humidity. Shade backfill, leaving all joints exposed so that they can be examined during pressure tests. On long runs pressure tests should be performed on sections no longer than 5,000 feet. Test pressure should be 150% of system design pressure and held at this pressure until the system is checked for leaks, or follow requirements of applicable code, whichever is higher.

Table H-5. Joint Cure Schedule

The following cure schedules are suggested as guides. They are based on laboratory test data, and should not be taken to be the recommendations of all cement manufacturers. Individual manufacturer's recommendations for their particular cement should be followed.

	Test Pressures For Pipe Sizes 1/2" to 1 1/4"		Test Pressures For Pipe Sizes 1-1/2" to 3"		Test Pressures For Pipe Sizes 3-1/2" to 8"	
Temperature Range During Cure Period	Up to 180 psi	Above 180 to 370 psi	Up to 180 psi	Above 180 to 315 psi	Up to 180 psi	Above 180 to 315 psi
60° - 100°F	1 Hr.	6 Hr.	2 Hr.	12 Hr.	6 Hr.	24 Hr.
40° - 60°F	2 Hr.	12 Hr.	4 Hr.	24 Hr.	12 Hr.	48 Hr.
10° - 40°F	8 Hr.	48 Hr.	16 Hr.	96 Hr.	48 Hr.	8 Days

Above cure schedules are based on laboratory test data obtained on NET Fit Joints (NET FIT = in a dry fit the pipe bottoms snugly in the fitting socket without meeting interference).

Relative humidity conditions in these tests were 50 percent or less. Higher relative humidities may require longer cure periods.

The same PPI Report contains an excellent series of illustrative cartoons showing the basic steps of jointing with solvent welds. (Copies may be ordered from the Plastics Pipe Institute, Division of the Society of the Plastics Industry, 250 Park Avenue, New York, New York 10017.) The cartoon series is ideal for field instruction and training.

Both PVC and ABS plastic pipe joints are field welded with a solvent. This solvent is usually methyl ethyl ketone ($CH_3CO_2CH_2CH_3$) or a comparable substance. Most of the solvent volatilizes and some of the vapor is entraped within the pipe. At atmospheric pressure and room temperature methyl ethyl ketone vapor in air is combustible if present within the range of 1.8 to 9.5 percent by volume bases. The liquid is also flammable, having a flash point of approximately 25°F. Thus a potential *explosion hazard* exists when the vapor from the solvent remains in the pipe. Moreover, if upon completion of the pipeline the water is turned on quickly, the gaseous mixture in the pipeline is compressed and the chance of explosion is increased. Thus an explosion may occur even though calcium hypochlorite granules or tablets are not inserted in the pipeline.*

Hypochlorites are powerful oxidants and react readily with foreign substances. They must be handled and stored in strict conformance with the manufacturer's instructions. With calcium hypochlorite in solid form, implements used must be clean and dry; if they are contaminated by oil and grease or by various other substances, combustion could result. Insertion of granular or tablet calcium hypochlorite in the pipeline would increase both the chance and magnitude of a violent combustion.

The following *safety precautions,* therefore, should be observed in conjunction with the use of solvent weld plastic pipe:

a. Calcium hypochlorite *in granular or tablet form* should not be inserted in PVC or ABS plastic pipe.

b. Air should be permitted to circulate through the pipeline to permit the solvent vapor to escape.

c. Upon completion of the pipeline the water should be admitted slowly to prevent compression of the gases within the pipe.

Such procedures will require the use of chlorine in solution, rather than the solid form of hypochlorites, for disinfecting the pipe and careful attention to forcing all air and gases from the pipe.

The *backfilling of solvent welded lines* should be progressive, i.e. the fill should be applied continuously from one end. Adjacent sections of line may of course, be filled simultaneously, if the final interconnection is left until backfilling is almost complete. Where a non-positive joint is used (e.g. at a valve) in an otherwise positively jointed line, it must be remembered that

*Only one instance, involving incredible carelessness, is known to the authors. If AWWA Std. C601-68 is followed, the hazard is no greater than for pipe of other material.

temperature movement will tend to accumulate at that point. Care should be taken to ensure that movement does not exceed the maximum telescopic movement afforded by the joint. Where rubber ring joints are used, the temperature movement of each pipe length is absorbed within that length.

An exception to the foregoing might be pipes carrying hot industrial effluent where temperature variation might necessitate special provision for expansion and contraction. In such cases guidance should be sought from the manufacturer.

There are two categories of *rubber ring joints:* those of the loose collar type where the collars are double ended with a rubber ring located in a groove at each end, used in conjunction with pipes which have chamfered spigots at each end; and the other type which has a socket either affixed to the pipe by the manufacturer, or factory-formed on one end of the pipe from the parent material of the pipe itself. The socket contains a groove in which a rubber ring is placed and the joint is made by inserting the spigot of the next pipe.

Such joints often require the application of a lubricating paste and this is normally supplied by the pipe manufacturer. Where natural rubber rings are supplied, mineral oils must not be used as a lubricant. Rubber ring joints are not end-load bearing.

When it is necessary to cut plastic pipe in the field, square cuts are essential. A conventional saw and a 90° miter box may be used when care is exercised or a pipe cutter with special blades for plastic material.

If a field cut is made, be sure to copy the guide mark provided on each pipe joint end. This mark allows you to know that you have inserted the pipe to the fitting stop.

The best field bevels are quickly made with a manual beveling tool. The nature of PVC piping material does allow hand beveling with a file, but the factory bevel angle should be maintained if assembly effort is to be minimized.

Fittings and rings (rubber rings should conform to ASTM D-1869) are delivered in boxes to assure a clean, undamaged joint. String the fittings only shortly before joining. To make a clean and unobstructed joint, it is necessary to wipe the ring, groove, and pipe spigot free from all foreign materials at the time of assembly. Dirt may collect on joining areas if this practice is not followed.

Install the ring with the holes on the flat surface facing inside the fitting and the radius surface facing the fitting entrance. Make sure the ring is not twisted or turned to prevent proper seating in the groove.

Apply the lubricant to the ring surface that is now exposed (never to the groove) and to the pipe spigot. Smear the lube on the pipe from the taper to the guide mark. Use only approved lubricant supplied or recommended by pipe manufacturer. Manufacturers can supply estimates of lubricant requirements.

Push the pipe and fitting together with one quick easy motion. The guide mark on the pipe should reach the end of the fitting. This guide is placed on many pipes 3 7/8" (plus or minus 1/8") from the end.

Two men may install PVC pipe of 6-inch or less diameter with ease--one man to apply the lubricant and one man to push from the unjoined end of the pipe. Greater speed may be attained if a third man assists in lubricant application.

If trench width permits, PVC pipe may be assembled in the trench. Pipe joined above the trench may be lowered by either of two methods.

a. It may be lowered into the trench by propping the last joint up with a board and moving it down to the next joint as assembly is made. This technique facilitates alignment for joining and places the completed joint in the trench. This practice is recommended for 5" and 6" diameter PVC pipe.

b. Pipe sizes up through 4" may be assembled into 200-foot long strips at ground level and rolled into the trench. During the lowering operation, one man should apply pressure against the unjoined end of the string to insure that none of the pipe ends slip back from the seating. After lowering, examine the end of the coupling to see that the guide mark on the pipe has not moved more than 1/4" from the end of the fitting.

To facilitate alignment for assembly, the last joint assembled must be propped up by a timber to keep it from dropping into the trench.

PVC pipe with rubber-ring joints can be laid on a curve with up to 5° deflection at each joint, allowing a minimum radius of about 250 feet for pipe lengths of 20 feet. Manufacturers should be consulted for permissible curvature for given joints and pipe.

A wide range of injection molded PVC *fittings* for use with PVC pipe is available in sizes up to and including 6 inch nominal diameter bends (90 degree and 45 degree) and reducers. A limited range of 8-inch PVC fittings is available at present. Certain limitations in regard to pressure rating are applicable.

PVC adaptors are available which, when solvent welded to the ends of PVC pipes, bring the outside diameters of the pipe ends to that of cast iron or asbestos cement. This enables connections to be made readily to these materials and allows special fittings, made primarily for these materials, to be used in PVC pipelines. Care must be taken to avoid overtightening bolted or screwed mechanical joints, as this may cause necking of thin-walled pipes over a long period.

PVC pipes must not be used with run lead joints.

To make service connections a range of saddles, of both the wedge and bolted type is available. Normal tapping methods and machines, but with special cutters for PVC pipes, may be used together with a range of ferrules giving outlets to pipes of polyethylene, copper, stell, PVC, etc.

5.05 Disinfection

There are a few instances where difficulties have been experienced in the disinfection of new PVC water mains incorporating *mechanical joints,* before putting these into service. The difficulty sometimes arises because the disinfecting agent does not penetrate into the annual space on the pressure side of the rubber jointing ring. If a greasy lubricant is used to assist in sliding the rubber ring into position, or if the end of the pipe has been wetted with water from the trench for the same purpose, these would compound the problem, but there must always be some risk of contamination from the handling of the ring and pipe spigot during laying. One precaution would seem to be the application of chloride of lime powder or solution during the forming of the joint, or the use of a lubricant containing a sterilizing agent.

5.06 Installing Submersible Pumps

The following instructions are extracted from a manufacturer's (Yardley) catalog:

Materials

Pipe: PVC 160 or ABS Sch. 160, 20 ft. lengths, plain end or coupled one end with fabricated fittings. (Molded fittings not recommended for vertical settings.)

Fittings: Fabricated fittings, couplings, male and female adapters.

Installation Instructions

1. Inspect pipe and fittings carefully before assembly to detect any damage that may have occurred by improper handling or storage.
2. Lay out required amount of pipe in a string on the ground.
3. Begin assembly at the top of the string by inserting pipe through the well seal. To insure tight fit of pipe to seal, use a brushing between the pipe and the seal.
4. Cement a male or female adapter above the well seal.
5. Begin assembly of pipe from the well seal down by cementing coupled lengths together.
6. Before cementing on the third length of pipe from the pump, slide a 4" or 6" Tork Stop on the pipe.
7. On the first length of pipe above the pump, slide on two Tork Stops. One will be under the coupling between the first and second joints; the other to be fastened in place as close to the pump as possible. (See drawing.)
8. Screw a fabricated male adapter into pump outlet.
9. Cement pump male adapter to pipe and pipe string is complete.
10. String the power cable through the Tork Stops and tape to pipe column on spacings not less than ten feet apart.
11. Fasten support and pull-wire or rope to neck of pump. Many installers tie support cable to pipe column the same as power cable. String cable through Tork Stops and bring through the well seal or up the outside.
12. You are now ready to install the assembly, as illustrated. A notched wood block under a coupling will support the assembly if necessary.

Support Cable or Rope

This serves two purposes:

1. To give added safety factor and to protect against loss of pump if improper joints are made.

11. As an aid in raising or lowering the pump if repairs are necessary. (Be sure cable is fastened securely to pump and top of well.)

Tork Stops

This device will not stop the pump torque. It will, however, keep the power cable from abrading against the casing or rock sides of the well. A minimum of three should be used; one at the pump; one at the top of the first joint; one at the top of the second joint. Location of Tork Stops over or under coupling is important--they are made of polyethylene and will float.

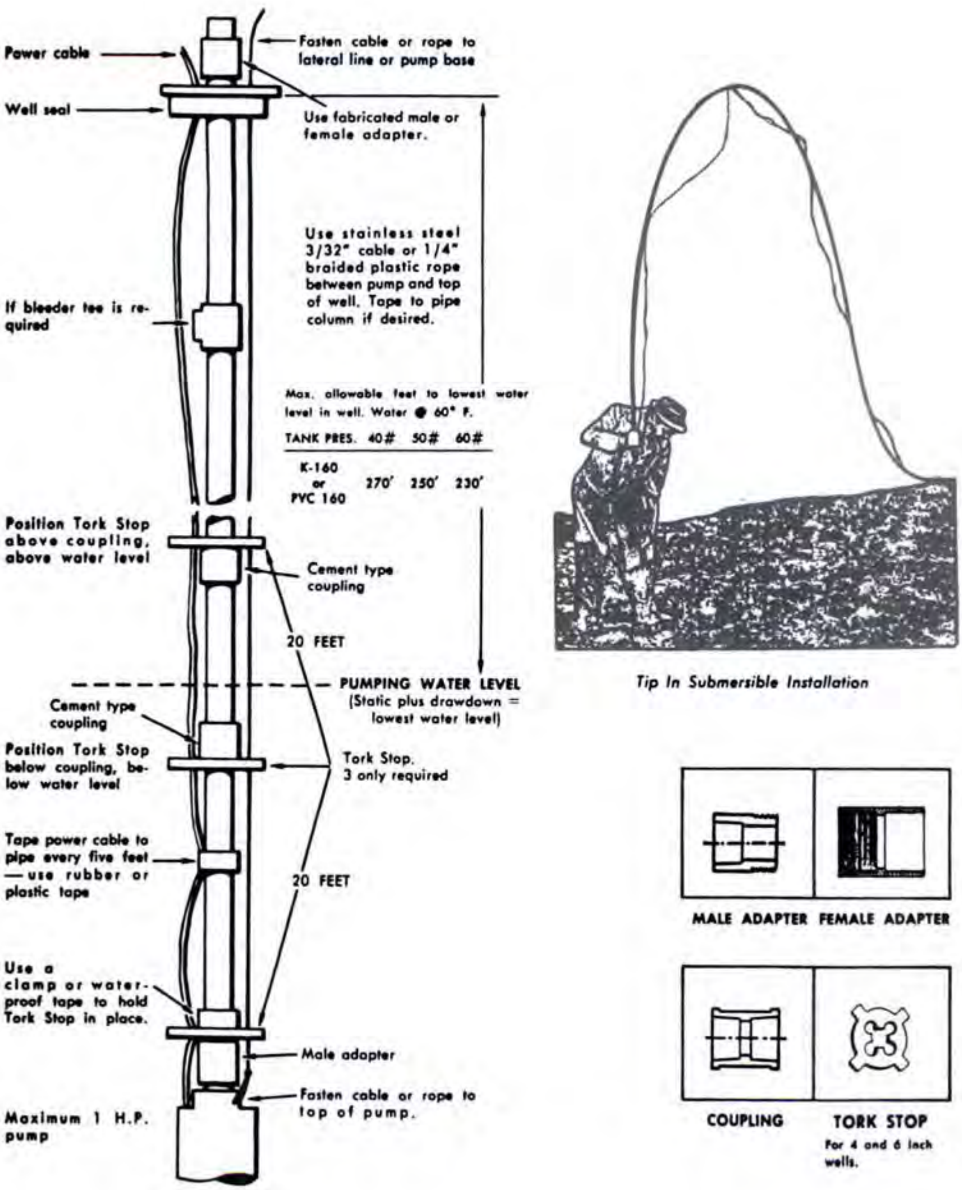

Figure H-2

INSTALLATION OF A SUBMERSIBLE PUMP USING PLASTIC PIPE

Cementing Recommendations

The cement recommended is PVC cement, a special solvent welding liquid made specifically for PVC or ABS pipe. (Use K Cement and Thinner with ABS.) It is furnished with a viscosity of molasses. It is highly volatile. Cans must be kept closed or evaporation will thicken the solution.

The set up time is very rapid. Be prepared to make the assembly before applying the cement joint, fitting by fitting. If the following steps are followed a permanent leakproof joint will result.

1. Make certain there is a tight fit between pipe and fitting before applying cement. Pipe should not enter fitting more than one-quarter of the socket depth. Fitting and pipe must be free of moisture and dirt.
2. Apply cement to end of pipe with a pure bristle brush in a continuous band approximately the length of the fitting socket.
3. Apply cement to the inside of the fitting socket same as above.
4. Push pipe into fitting with a rotating motion until it meets stop in fitting to insure complete cement coverage.
5. Wipe off any push back that forms a bead between pipe and coupling.
6. When above instructions are followed, the resulting joint will be sufficiently strong in approximately ten minutes from time of joining the pipe and fitting to withstand 40-50 psi. NOTE: Dampness in air has a tendency to "slow" the rate of cement evaporation, thus lengthening the time interval from connection of pipe and fittings to pressure application.
7. Before starting tip-in installation wait at least 30 minutes to be sure last joint is thoroughly set up. This time can be used for installing the power and support cables.

INSTALLING ACRYLONITRILE–BUTADIENE–STYRENE (ABS) PLASTIC PIPE

6.01 Properties

Acrylonitrile-butadiene-styrene (ABS) material is medium in design stress between PE and PVC. It offers greater resistance to mechanical shock than PVC. It has excellent corrosion and mechanical resistance. It is notch sensitive in thin-wall pipe, as is PVC, and may be damaged by sharp rocks or objects. The pipe is rigid and comes in lengths of approximately 20 feet. It is lightweight (sp. gr. 1.1) and is available in both iron pipe and steel water pipe sizes. It is sensitive to ultraviolet light but with the addition of carbon black an opaque pipe is produced which has excellent weathering ability.

It is suitable for transmitting potable water, shows excellent resistance to salts and alkalis and to a large number of organic compounds. Resistance to most acids is excellent although high concentrations of some of the stronger acids show some attack. It is readily attacked by aromatic hydrocarbons, halogenated carbons as well as by the esters and ketones.

ABS plastics (ASTM D 1788) cover a wide variety of materials that are relatively rigid, easy to mold and extrude and have a high impact strength at both room and low temperature. The hydrostatic design stresses for water at 73°F are 800, 1000, 1250 and 1600 psi. These materials are useful at temperatures of 140°F and somewhat higher depending on the compound. There is one being used at 180°F.

The pipe is available with fittings of all types and connecting joints may be made by screw-threaded couplings, solvent welds, or Dresser-type joints, among others, ABS pipe with special fitting requirements include:

ABS-SWP: SWP denotes that this pipe is of a special outside diameter not otherwise found in piping materials. Only solvent welded fittings marked SWP can be joined to this pipe. Threaded or grooved joints are made with adapters.

Sch. 160: I.P.S. OD has standard iron pipe outside diameters but is not recommended for threading, except in sizes 3″ and 4″. For smaller sizes use solvent welded fittings marked IPS.

Sch. 80 is manufactured to iron pipe Schedule 80 or extra steel pipe dimensions. Fittings can be joined to Sch. 80 by threading, grooving or solvent cement methods. Those fittings designated threaded or IPS can be used with Sch. 80.

6.02 Handling and Storing

Same requirements as for PVC (see Sections 3.01, 5.02).

The following spacing between supports is recommended for overhead or elevated ABS lines.

Table H-6. Support of Elevated ABS Pipe

Pipe Size	Supports on Centers
1″ or less	48″ maximum
Larger than 1″	24″ maximum

6.03 Joining

With ABS material, essentially the same methods of installation and precautions apply as for PVC material, with the exception that ABS pipe appears to be more adversely affected by heat than PVC. It is suggested that heat forming be avoided.

In cementing ABS pipe*:

1. Pipe should be cut square and burrs removed. Be sure pipe end and fitting socket are clean and dry.
2. Try fitting on pipe, dry. Use pure bristle brush to apply even cement coat to fitting socket. Flow a generous flood of cement onto end of pipe. Most joint failures are caused by insufficient cement on pipe.
3. Insert pipe into fitting immediately using twisting motion (¼ turn) until pipe bottoms in socket. Wipe off excess cement. If cement has partially dried reapply as in Step 2.
4. After 10 minutes joint will be sufficiently strong to permit limited handling. Avoid twisting or distorting the joint during this time. Do not ditch before at least 4 hours.

*See ASTM D 2235-63T for tentative specification for solvent cement for ABS plastic pipe and fittings.

5. Piping assemblies through 1 1/2 inch size may be tested to 45 psi after 2 hours drying time; 2 inch and larger after 4 hours. Allow 24 hours drying to achieve full joint strength.
6. Plastic pipe contracts and expands as much as 1 inch per 20 feet length. Provide for this, particularly on installations made during hot weather, by snaking in ditch or running line on open discharge until it contracts to operating length.
7. Exercise care in handling. Don't manhandle the pipe, or subject it to unnecessary strains, such as excessive bending or twisting. Before installing pipe in ditches, backfill the ditch with soft earth. Cover pipe carefully, you may fracture the pipe, which will leak after pressure is applied.
8. If cement thickens, use thinner.

To *thread Sch. 80 pipe* only, standard hand or power pipe threading equipment can be used. Cutting tool rake angle of 5° gives best results; lead angle, etc. remain the same. Tapered plugs are suggested for sizes over 1 1/2 inch during threading operation. Coolants are not necessary. Do not use cement on threads or threaded joints. Use pipe dope on threaded joints. Teflon tape is also applicable for use with ABS threaded joints.

6.04 ABS for Drain, Waste, and Vent (DWV) Installations

In 1965 ABS moved into large scale production when it was accepted by the Building Officials Conference of America (BOCA) for drain, waste and vent installation. It was estimated in 1966 that ABS pipe was used for 10% of the DWV installations in new houses built that year and for practically all of the mobile homes.

Handling and Storage

Same requirements as for PVC.

Joining

1. Cut pipe end square, remove ragged edges and burrs.
2. Remove any dirt from pipe end and fitting socket.
3. *Apply light thin coat solvent cement to fitting socket.
4. *Apply heavy coat solvent cement to pipe end. Apply to pipe end to a length equal to fitting socket depth.
5. Insert pipe in fitting socket with rotating motion, till it butts on stop of fitting socket.
6. Remove excess solvent cement from exterior of joint with a clean cloth.
7. Reasonable handling of completed joint is permitted in 3 to 4 minutes. Stack testing can be conducted in 10 minutes after joining.
8. Never disturb joint after solvent cement is set. If disturbed, replace pipe and fittings at that point.
9. Should any delay develop in assembly, apply additional coating of solvent cement as per 3 and 4 above.
10. Do not thread pipe or tap fittings.

*Use a brush with natural bristles.

Use of Thread Lubricant

Petroleum jelly (Vaseline) or teflon tape thread lubricants are recommended for use on male or female plastic fitting threads. These pipe dopes are known to be applicable for use with ABS Type I and IA plastic fittings. The use of pipe dope facilitates the removal of threaded joints. Any other thread lubricant (pipe dope) should be checked for compatibility with ABS I and IA before use.

Pipe Suspension

All DWV piping should be supported at intervals of not more than four (4) feet. Trap arms should always be supported as close as possible to the trap. Pipe should also be supported at all branch ends and at all points in change of direction. Strap type metal hangers are recommended. Care should be used when applying hangers to avoid compression or distortion of pipe.

General

DWV drainage fittings are molded with a pitch to effect a 1/4″ slope per foot.

Connect traps to DWV with male or male fitting adapters which are solvent welded to the plastic fixture drain.

DWV pipe and fittings are marked on both sides of pipe barrel and fitting where possible.

Solvent Cement

Follow pipe manufacturers recommendation on solvent cement to be used with his pipe and fittings.

Solvent cement is packaged ready for use from its original container. Apply it with a natural bristle brush.

Solvent cement is inflammable and should not be used near a fire or flame. Prevent prolonged contact with skin and it should not be inhaled. Use solvent cement in ventilated area. The minimum time before initial set should be 3 minutes at 50°F, 2 minutes at 70°F, and 1 minute at 90°F.

Thinner

Thinner is used to thin solvent cement to its original state. Solvent cement is in its proper state when it has a viscosity of 100 to 115 KREBS units when determined with a Stormer Viscosimeter at 77°F. This thinner may be used to clean brushes used with solvent cement.

Storage

Outdoor storage of pipe is satisfactory but should be protected from sunlight. Most satisfactory results are obtained if pipe and fittings are kept clean and brought to room temperature before use. Pipe should have 100% support in stock. Use no spacers.

APPENDIX I

PLASTIC PIPE FOR SEWERS

Introduction

Plastic sewer and drain pipe, first produced in 1946, grew rapidly in acceptance and by 1961 there were over 50 million feet of such pipe in service in the United States alone. During 1961 an estimated 25 million feet were shipped, accounting for some 20 million pounds of raw material and representing a sales volume of about $8 million (including fittings). This growth is continuing with annual sales volume doubling within this decade.

Plastic pipe has many advantages for use as sewer pipe. It is not affected by corrosive soils, aggressive waters, domestic sewage and most industrial wastes. A glassy smooth interior surface free from encrustation or attack assures a permanently high carrying capacity. Plastic pipe's low "n" factor allows pipe to be laid on flatter grades. Diameter for diameter it will carry more sewage than pipe of most other materials laid to the same grade. Tight joints eliminate infiltration and leakage; also root penetration. A wide range of fittings is available.

The pipe is light in weight - two 20 foot lengths of 4-inch diameter plastic pipe weighs less than 5 feet of the same diameter cast iron pipe. Long lengths are avialable up to 35 feet reducing the number of joints. Jointing is simple and fast, also the installation of fittings, using either solvent welds or rubber-ring gasket joints. Adapters are available to other sewer pipe materials. Saddle type branch connections are quickly made without delay of other installation operations and they can be placed exactly where needed. The impact resistance of plastic pipe materially reduces breakage. Narrower trenches may be used with plastic pipe which may be joined on the ground surface beside the trench and then lowered into place.

Until recently the use of plastic pipe in sewer systems was limited to building and house sewers primarily because 6-inch diameter was the largest size available. In 1963 a specially designed plastic pipe, termed truss pipe, was introduced in sizes of 8-, 10-, 12- and 15-inch diameter. By August, 1968 nearly 3 million feet of truss pipe had been installed for sanitary sewers in 37 states in the United States. In 1967 a British manufacturer announced the production of extruded PVC pipe in diameters up to 16-inch with future possibility of producing 20-, 24-, and 30-inch pipe. Reinforced plastic mortar (RPM) sewer pipe composed of a mixture of mineral aggregate and polyester resin with continuous glass filaments is available in diameters from 8 to 48 inches. These developments have lead to the wider use of plastic pipe for sewers.

In addition to PVC and ABS, plastic sewer pipe is also made of styrene rubber covered by Commercial Standards CS-228-61. It is available in 2-, 3-, 4- and 6-inch diameters in 10 foot lengths and has a crushing strength of 1,000 pounds per linear ft. See Appendix C for other pertinent standards and specifications including those for ABS and PVC pipe.

Plastic pipe for sewers is available for non-pressure and pressure installations. Perforated plastic pipe may be obtained for use in septic tank drainage fields.

Approximate prices, quoted in 1967, are included in Table I-1 for comparative purposes.

Table I-1

Price of Plastic Pipe
(Approximate 1967 U.S. Prices for Uninstalled Pipe Only)

Diameter (inches)	Sewer Pipe Std. Grade	Pressure Pipe (100 psi)	Irrigation Pipe Lowhead (100 ft)	Perforated Drain
	(Prices - Dollars per lineal foot)			
2	0.28			
3	0.37			0.25
4	0.46			0.37
6	1.00			
12	2.50	3.40	2.60	
24	8.50	7.90	6.70	
36	14.80	13.20	11.90	
48	22.50	18.70	17.75	

Plastic pipe has been used effectively to reline sewer pipe which has become corroded, porous and leaks at the joints. A number of lengths of plastic pipe are solvent welded together above ground and mounted on rollers ready to be pulled down an excavated slope to the steel entrance. A wooden plug is secured to the leading end of the line and then a steel cable is fastened to the plug, threaded through the existing sewer line and fastened to a winch. The pipe is pulled into the sewer line as additional lengths are added, solvent welded and allowed to set.

Flow Characteristics of PVC Sewer Pipe

The most commonly used formula in sewer design has been the Manning formula and its reliability and usefulness has been proven by tests on all types of sewer pipe from clay to concrete. The Manning formula is valid, however, only for rough turbulent flow in which the surface roughness of the pipe itself is the prime factor in resistance to flow. On the other hand, for design purposes in pressure piping PVC pipe has been assumed to be a "smooth" pipe. The Hazen-Williams formula is used for designing flow of water under pressure in PVC pipe as this formula was designed for use with relatively smooth pipe flowing either full or partly full rather than for sewerage or drainage work in which, in the past, the pipe has been relatively rough.

The recent adaptation of PVC and other plastics for the manufacture of sewer pipe necessitated the determination of its flow characteristcs for design purposes. Tests performed in 1962* on PVC sewer pipe in 8- and 12-inch diameters indicated that for design purposes, conservative results are obtained by using the Manning formula with n = 0.009. The Hazen-Williams formula with a friction coefficient (C) of 155 gives results only slightly less accurate.

Handling, Storage, Installation

The same suggestions apply for the handling, storage and installation of ABS, PVC and SR plastic sewer pipe as for similar plastic pipe for water service. (See Appendix H)

Plastic Truss Pipe

Plastic truss pipe consists of two interconnected walls of acrylonitrile-butadiene-styrene (ABS) resin tied together by a truss of the same material, with the voids filled with lightweight concrete. The lightweight concrete in the voids of truss-type plastic pipe helps to carry the compressive load and provides lateral support for the truss members. Tensile stresses are carried by the pipe wall.

Characteristics

Truss-type plastic pipe is relatively light in weight and, because of its composition, is quite durable for sewer installations. It has a high resistance to abrasion, freezing, and thawing, and is not affected structurally at temperatures up to 130°F. Thermal expansion is not significant over normal installation ranges. This type of pipe is chemically resistant to hydrogen sulfide and acids in concentrations up to 5 percent.

Minimum specification (ASTM D-18617) for crushing strength is 1,500 lb per lin ft, but tests on 8-inch pipe show that between 60 and 130°F, the crushing strength ranges from 2,100 to 1,650 lb per lin ft.

Good hydraulic flow characteristics result from the smooth surface of the interior wall of the pipe. As produced, this type of pipe is stated to have a *Manning n value of 0.010.*

Manufacture and Testing

Truss-type plastic pipe is made by an extrusion process that forms both the walls and the truss arrangement simultaneously. Data on pipe sizes and weights are given in the following table.

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*Neale, Lawrence C. and Price, Robert E. "Flow Characteristics of PVC Sewer Pipe." *ASCE Proceedings,* Vol. 90, No. AS3, pp. 109-129 (Jan, 1964). This publication also contains design formulas and graphs.

Table I-2
Data on Truss-Type Plastic Pipe

Pipe Size: Regular Strength (in.)	Extra Strength (in.)	Length (ft.)	Weight (lb/lin ft)
...	4	6 1/4, 12 1/2	...
...	6	6 1/4, 12 1/2	...
8	...	6 1/4, 12 1/2	8
10	...	6 1/4, 12 1/2	11
12	...	6 1/4, 12 1/2	15
15	...	6 1/4, 12 1/2	26

Jointing

Jointing is accomplished by solvent welding to produce a sewer that is leakproof and resists root penetration and infiltration. A sleeve type coupling comes attached to one end of each pipe. To join the sections, the middle of the coupling and the plain end of another pipe section are coated first with a primer and than with a cement consisting of ABS in methyl-ethyl-ketone. Then the plain end is stabbed into the coupling. The only tool required is a common paint brush; should it be necessary to cut a length of pipe in the process, a hand saw will do the job.

A similar principal underlies the attaching of lateral connections. After cutting a hole into the main with a keyhole saw, primer and cement are used to fix a stub-saddle to the pipe and to connect to succeeding sections of the lateral house line to the saddle.

ASTM has issued a standard entitled ABS Composite Pipe (ASTM D-2680-67T) and this type of pipe has been approved for use in FHA-insured construction.

Reinforced Plastic Mortar (RPM) Sewer Pipe

RPM sewer pipe is made of a mixture of natural sand aggregate and polyester resin reinforced with continuous glass filaments. It is manufactured in the following nominal diameters: 8, 10, 12, 15, 18, 21, 24, 27, 30, 33, 36, 39, 42 and 48 inches. It is made with bell and spigot ends and joined with a rubber gasket.

The pipe is significantly lighter in weight than other materials. For instance a 24-inch diameter RPM sewer pipe weighs 32 lbs/ft compared to 155 lbs/ft for cast iron pipe, an advantage in handling, shipping and installation.

Installation

Conventional concrete pipe installation procedures are utilized, with the following major exceptions:

a) Since the wall thickness of RPM pipe is much less than that of reinforced concrete pipe, trench width for 24″ diameter pipe is only 36″ instead of the normal 48″.

b) Due to the above, it is possible to use a 36" trencher rather than the slower backhoe normally used by a contractor for 48" widths.

c) Due to the light weight of RPM pipe, several handling operations are performed by hand rather than by a boom.

d) Again due to the light weight, it is possible for one man to make up joints in a matter of seconds using only a prybar, as compared with the machine or power-assisted methods normally required.

On one typical installation of 24-inch diameter RPM sewer pipe a total of 5 hours working time was required as compared with a normal working time of 8 hours for the same length of reinforced concrete pipe.

Plastic-lined pipe

Steel pipe that has a plastic lining may be considered as plastic lined steel pipe; it also may be considered as steel armored plastic pipe.

The greatest used of plastic-lined pipe is in handling corrosive chemicals. Currently, the most important application of plastic-lined pipe in the wastewater field is in the disposal of chemical wastes into underground wells.

Design and Manufacture

Plastic-lined steel pipe is produced with three types of extruded liners, namely, saran, Penton, and polypropylene. These liners are tough and stabilized; they range in thickness from 5/32 to 9/32 in. They are locked in place on the inside of the steel pipe walls by a force of several thousand pounds per square inch. The result is a thick-walled pipe with a heavy steel shell, the two layers being virtually monolithic. The pipe thus produced is suitable for use at temperatures from -20 to 200°F or higher. Pipe is available in sizes from 1 to 8 in., weighing from 2.4 to 28.6 lb per ft; it is made in 10 ft lengths.

In another manufacturing process, a special polyethylene co-polymer is bonded to both the inside and outside of steel pipe. This type of pipe is produced in approximately 30-ft lengths, with coatings of plastic 30 mils thick. Pipe sizes (diameters) available include 2, 3, 4, 6, and 8 in. The weight of this pipe ranges from 1.73 to 10.7 lb per ft. Joints are couplings or flanges.

APPENDIX J

PLASTIC PIPE FOR GAS SERVICE

Introduction

The increasing use of plastic pipe in the gas industry is due to its favorable cost, ease of handling and installation, light weight, flexibility, flow characteristics, freedom from corrosion, rust, and galvanic and electrolytic action, and low cost maintenance (estimated by some to be as much as 60% less than for metal pipe).

The mounting popularity of plastics piping by gas distribution companies is illustrated by an industry survey showing that in 1955, twenty-nine gas companies used 500,000 feet; in 1966, eighty-five companies used 11,200,000 feet. Plastic pipe was used in 48.9% of new mains in 1965.

An editorial comment in the *Plastics* magazine (English) of August, 1967 stated: "Swifter changeover to PVC instead of steel and cast iron pipe by Britain's gas boards could save the country at least £27 million per year. 8% of total gas supplies is lost per day between gas holder and user. That is 160 million cubic feet or 800,000 therms equal; at 1s 10d per therm to just under £27 million per year. It cannot be claimed that large scale changeover to PVC would entirely eliminate this loss - which is generally thought to be due to leaking joints, corrosion and subsidence - but new pipes of PVC which has already proved its suitability in Britain and other European countries for both town and natural gas, would go a long way toward solving the problem. These figures leave out of consideration the large savings derived not only through the much simpler installation techniques associated with plastic pipe, but also its other inherent advantages such as resistance to corrosion, light weight and so on."

Piping Systems

Piping systems in the gas industry consist of (a) gas mains, or distribution lines, commonly run under the street, parallel to the curb, and ranging in size from 2-inch to 12-inch diameters; and (b) service lines run perpendicular to the curb, connecting the distribution main to the customer service, and ranging in size from 3/4-inch to 1 1/2-inches. Distribution lines are usually classified into three categories: 2 psi or less, generally referred to as utilization pressure; 60 psi and 120 psi. The latter two categories mostly comprise the longer lines supplying the regulation which reduces the pressure to the utilization value. Distribution lines are not to be confused with cross-country transmission lines which include pipes 36 inches in diameter operating at pressures of up to 1,000 psi.

Rigid, long lengths (20 to 40 feet) of pipe are preferred for mains. The rigidity aids in maintaining the slight grade or slope that is required to avoid the pockets or bellies that collect condensates containing water, anti-freeze, odorants and hydrocarbons. These condensiates could block off or retard the flow of gas.

Early Use of Plastics Pipe

The earliest commercial use of plastic pipe in the gas industry predated general recognition of the advantages of these materials. It arose out of necessity during World War II due to growth brought about by the war effort and the short supply of cast iron, steel and copper piping. Pipe made of cellulose acetate butyrate (CAB) was available and over 3 million feet was used by one west coast company in 1943.

Some failures were encountered during early installation. These were attributed by an American Gas Association survey to (a) 55% due to improper design, improper installation procedure and poor workmanship; (b) 25% due to defects in the plastic pipe material and fabrication; (c) 8% due to environmental effects and (d) 12% which could not be properly identified.

Current Practice

Since that time a very considerable amount of experience and technical data have been amassed; ASTM D2513-68, "Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing and Fittings", as well as American Standards Association ASAB 31.8, "Code for Pressure Piping, Gas Transmission and Distribution Piping Systems"* have been issued; extensive plastic pipe studies have been carried out by the Batelle Memorial Institute which have led to the development of lists of criteria by which the suitability of plastic pipe for gas may be judged. (A copy of the list is included at the end of this Appendix).

ABS, CAB, PVC and high-density PE plastic pipe are usually recommended for natural gas distribution. The long term effect of natural gas has been shown to be essentially equivalent to that of water for four kinds of plastic pipe, ABS 1210, PVC 2110, PE 3306 and CAB MHO8 (See ASTM 2513-68, A2.4 Environmental Effects). Because the major thermoplastics are affected by aromatics, concern exists over the possible effects of the use of synthesis gases (gases reformed from oil stock) to supplement natural gas requirements during peak load periods. These synthesis gases contain benzene, toluene, and other aromatics. Where such constituents may be present, the choice of a plastic must be made with greater care and if sufficiently high concentrations are present, aromatic-resistant plastics will have to be used. In those areas where anti-freezes are either added to the gas to prevent freeze-ups or used in

*In 1967 plastic pipe was included officially and specifically in ASA B31.8. Before that it was not mentioned in the Code but included under a clause allowing installation of pipe on a limited experimental basis.

Reference is made to ASTM D 2513-68 and ASA B31.8 for standards, specifications, test methods, preferred practices installation procedures, design procedures for various end-use conditions, safe working conditions and other detailed information.

concentrated form to defrost a frozen section, the choice of plastics must be made with greater care. Certain polyethylenes, for example, will crack if stressed while exposed to the anti-freezes or other substances that induce environmental stress cracking.

American Gas Association Subcommittee on Plastic Pipe Standards

Criteria for Evaluation of Plastic Pipe and Fittings Intended for Transport of Gas

March 23, 1964

The following criteria have been stipulated as being desirable of a candidate plastic pipe for use in gas distribution systems. The sub-committee recognizes that not all of these factors are equally important for each kind of plastic pipe. It also recognizes that no numerical limits can be set for any new pipe. However, presentation of all these data to the sub-committee will undoubtedly speed the committee's action regarding the pipe in question.

1. Long-term strength with gas (methane), at 73°F and, at least, one higher temperature (100°F). If data for gas are not available, report data for water. PPI method plus ASTM D1598 with proposed gaseous fluid modification. Report type and change in fracture pattern or behavior.
2. Creep (cold flow), compressive.
3. Burst pressure with water, ASTM D1599, 60 to 90 seconds.
4. Flattening, extent or degree without rupture. CS 256 (PVC Pipe) or proposed ASTM-PPI parallel plate test when approved.
5. Crush properties, parallel plate, stiffness factor and crush load. Proposed ASTM-PPI parallel plate test when approved.
6. Impact resistance, dropweight on pipe, -10°F, 32°F and 73°F. Proposed ASTM-PPI Pipe and Fitting Impact Test when approved.
7. Linear coefficient of thermal expansion, at least over the range of -40°F to +120°F.
8. Water absorption. ASTM D570.
9. Methane permeability.
10. Chemical resistance, immersion, effect on one or more sensitive properties.
    - 10.1 All materials, ASTM D543 procedure with the following chemicals: heptane, toluene, methanol, isopropanol, t-butyl mercaptan, ethylene glycol, strong acids, and strong bases. (See Note 1.)
    - 10.2 Specific materials, as indicated by the following: PVC acetone immersion ASTM D2195; ABS acetic acid immersion ASTM D1939; PE environmental stress cracking test in ASTM D2104-62; CAB acetone immersion; and other materials with any chemical or chemicals believed to be pertinent.

      Note 1. Toluene and t-butyl mercaptan will dissolve some plastic pipe materials; these should simply be noted.
11. Effects of weathering, actual outdoor exposure and laboratory tests.
12. Effects of aging under stress (internal gas pressure).

13. Fabrication peculiarities and tests for same (See Item 10.2).
14. Methods of joining and tests for same. Test for fusion.
15. ASTM materials specifications, designation number, type and grade, if any.
16. Standards for pipe and fittings: Is enough known to prepare reasonably good standards for the product?
17. Pipe and fittings for which data are submitted herein; dimensions (sizes), color, trade or commercial designation.
18. Any other property values or data deemed to be pertinent. Consider chemical nature of plastic material and characteristics peculiar to the plastic from which the pipe and fittings are made.

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