

Chapter 4

PE Pipe and Fittings Manufacturing

Introduction

The essential steps of PE pipe and fitting production are to heat, melt, mix and convey the raw material into a particular shape and hold that shape during the cooling process. This is necessary to produce solid wall and profile wall pipe as well as compression and injection molded fittings.

All diameters of solid wall PE pipe are continuously extruded through an annular die. Whereas, for large diameter profile wall pipes, the profile is spirally wound onto a mandrel and heat-fusion sealed along the seams.

Solid wall PE pipe is currently produced in sizes ranging from 1/2 inch to 63 inches in diameter. Spirally wound profile pipe may be made up to 10 feet in diameter or more. PE pipe, both the solid wall type and the profile wall type, are produced in accordance with the requirements of a variety of industry standards and specifications such as ASTM and AWWA. Likewise, the PE fittings that are used with solid wall PE pipe are also produced in accordance with applicable ASTM standards. Refer to Chapter 5 for a list of the commonly used PE pipe standards.

Generally, thermoplastic fittings are injection or compression molded, fabricated using sections of pipe, or machined from molded plates. Injection molding is used to produce fittings up through 12 inches in diameter, and fittings larger than 12 inches are normally fabricated from sections of pipe. Refer to Chapter 5 for a list of the commonly used PE fittings standards.

ASTM F2206 Standard Specification for Fabricated Fittings of Butt-Fused Polyethylene (PE) Plastic Pipe, Fittings, Sheet Stock, Plate Stock, or Block Stock.

All of these pipe and fittings standards specify the type and frequency of quality control tests that are required. There are

several steps during the manufacturing process that are closely monitored to ensure that the product complies with these rigorous standards. Some of these steps are discussed in the section of this chapter on quality control and assurance.

Pipe Extrusion

The essential aspects of a solid wall PE pipe manufacturing facility are presented in Figure 1. This section will describe the production of solid wall pipe from raw material handling, extrusion, sizing, cooling, printing, and cutting, through finished product handling. Details concerning profile wall pipe are also discussed in the appropriate sections.

Raw Materials Description

The quality of the starting resin material is closely monitored at the resin manufacturing site. As discussed in the chapter on test methods and codes in this handbook, a battery of tests is used to ensure that the resin is of prime quality. A certification sheet is sent to the pipe and fitting manufacturer documenting important physical properties such as melt index, density, ESCR (environmental stress crack resistance), SCG (slow crack growth), stabilizer tests, amongst others. The resin supplier and pipe manufacturer may agree upon additional tests to be conducted.

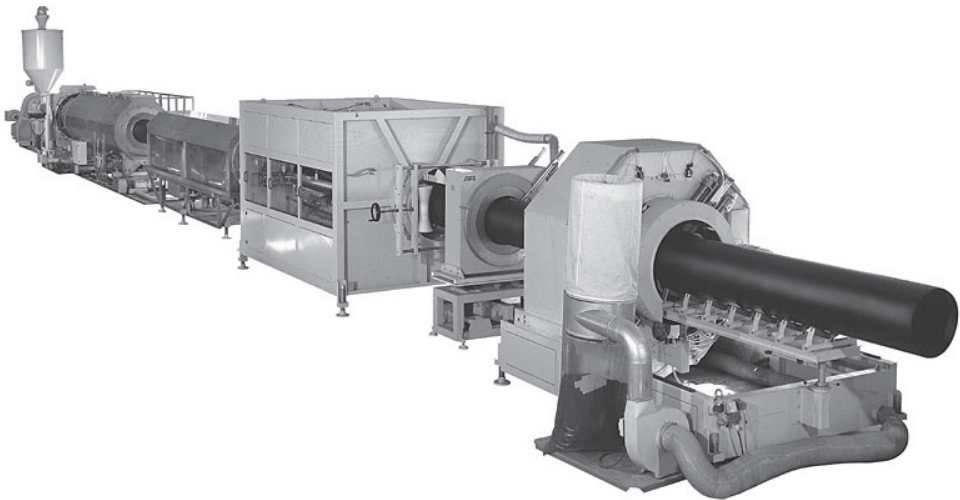


Figure 1 Typical Conventional Extrusion Line

Extrusion Line

The raw material, usually referred to as PE compound, is typically supplied to the pipe producer as non-pigmented pellets. PE pellets are stabilized for both heat and UV protection. Usually, color pigment is added to the pipe at the producer's facility. In North America, the most common colors are black and yellow. The choice of color will depend upon the intended application and the requirements of the pipe purchaser. Carbon black is the most common pigment used for water, industrial, sewer and above-ground uses. Yellow is reserved exclusively for natural gas applications, although black with yellow stripes is also permitted for this application. Other colors are used for telecommunications and other specialty markets.

All ASTM and many other industry standards specify that a PPI-listed compound shall be used to produce pipe and fittings for pressure pipe applications. A compound is defined as the blend of natural resin and color concentrate and the ingredients that make up each of those two materials. The pipe producer may not change any of the ingredients. In a listed compound, such as substituting a different color concentrate that could affect the long-term strength performance of the pipe. Any change to a listed formulation has to be pre-approved. These stringent requirements ensure that only previously tested and approved compounds are being used.

If the resin is supplied as a natural pellet, the pipe producer will blend a color concentrate with the resin prior to extrusion. In order to obtain a PPI Listing, each manufacturer producing pipe in this manner is required to submit data, according to ASTM 2837, to the PPI Hydrostatic Stress Board. A careful review of the data is made according to PPI Policy TR-3 ⁽⁵⁾ to assess the long-term strength characteristics of the in-plant blended compound. When those requirements are met, the compound qualifies for a Dependent listing and is listed as such in the PPI Publication TR-4 ⁽⁶⁾, which lists compounds that have satisfied the requirements of TR-3. Producers of potable water pipe are usually required to have the approval of the NSF International or an equivalent laboratory. NSF conducts un-announced visits during which time they verify that the correct compounds are being used to produce pipe that bears their seal.

Raw Materials Handling

After the material passes the resin manufacturer's quality control tests, it is shipped to the pipe manufacturer's facility in 180,000- to 200,000-pound capacity railcars, 40,000-pound bulk trucks, or 1000- to 1400-pound boxes.

Each pipe producing plant establishes quality control procedures for testing incoming resin against specification requirements. The parameters that are typically tested include: melt flow rate, density, moisture content and checks for

contamination. Many resin producers utilize statistical process control (SPC) on certain key physical properties to ensure consistency of the product.

Resin is pneumatically conveyed from the bulk transporters to silos at the plant site. The resin is then transferred from the silos to the pipe extruder by a vacuum transfer system. Pre-colored materials can be moved directly into the hopper above the extruder. If a natural material is used, it must first be mixed homogeneously with a color concentrate. The resin may be mixed with the color concentrate in a central blender remote from the extruder or with an individual blender mounted above the extruder hopper. The blender's efficiency is monitored on a regular basis to ensure that the correct amount of color concentrate is added to the raw material.

Extrusion Basics

The function of the extruder is to heat, melt, mix, and convey the material to the die, where it is shaped into a pipe⁽⁸⁾. The extruder screw design is critical to the performance of the extruder and the quality of the pipe. The mixing sections of the screw are important for producing a homogeneous mix when extruding blends. A typical extruder is shown in Figure 2.

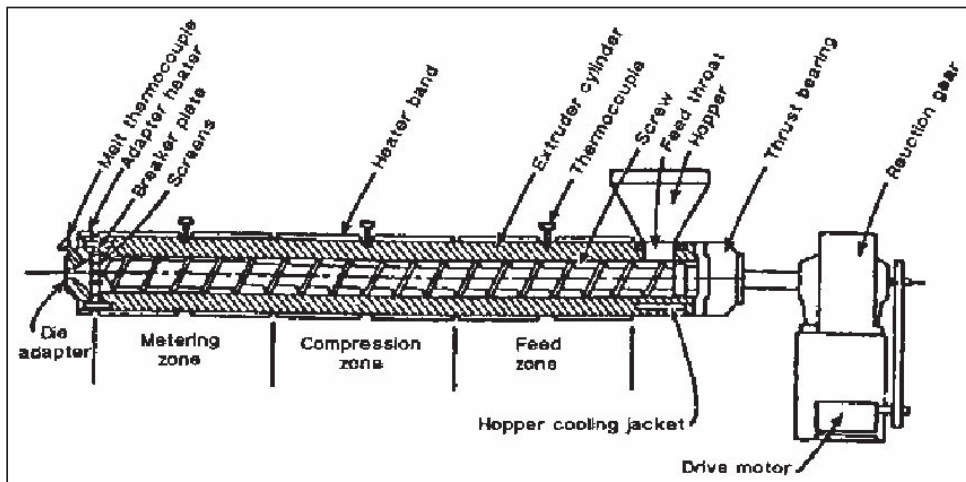


Figure 2 Typical Single-Stage, Single-Screw Extruder (Resin Flow from Right to Left)

There are many different types of screw designs⁽¹⁰⁾, but they all have in common the features shown in Figure 3. Each screw is designed specifically for the type of material being extruded.

The extruder screw operates on the stick/slip principle. The polymer needs to stick to the barrel so that, as the screw rotates, it forces the material in a forward direction.

In the course of doing this, the polymer is subjected to heat, pressure and shear (mechanical heating). The extent to which the material is subjected to these three conditions is the function of the screw speed, the barrel temperature settings and the screw design. The design of the screw is important for the production of high quality pipe.



Figure 3 Typical Extrusion Screw

If a natural resin and concentrate blend is used, the screw will also have to incorporate the colorant into the natural resin. Various mixing devices are used for this purpose as shown in Figure 4. They include mixing rings or pins, fluted or cavity transfer mixers, blister rings, and helix shaped mixers, which are an integral part of the screw.

The pipe extrusion line generally consists of the extruder, die, cooling systems, puller, printer, saw and take-off equipment. Each of these items will be addressed in the following section.

Figure 4 Typical Resin Mixing Devices

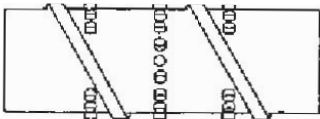


Figure 4.1 Mixing Pins

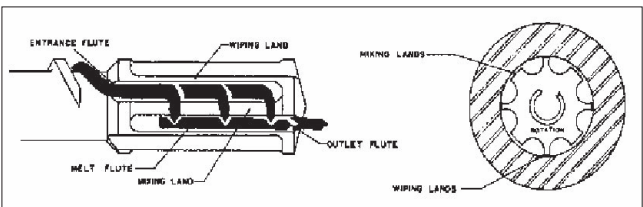


Figure 4.2 Fluted Mixer

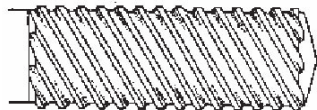


Figure 4.3 Helical Mixer

Extruders

An extruder is usually described by its bore size and barrel length. Pipe extruders typically have an inside diameter of 2 to 6 inches with barrel lengths of 20 to 32 times the bore diameter. The barrel length divided by the inside diameter is referred to as the L/D ratio. An extruder with an L/D ratio of 24:1 or greater provides adequate residence time to produce a homogeneous mixture.

The extruder is used to heat the raw material and then force the resulting melted polymer through the pipe extrusion die. The barrel of the machine has a series of four to six heater bands. The temperature of each band is individually controlled by an instrumented thermocouple. During the manufacturing process, the major portion of the heat supplied to the polymer is the shear energy generated by the screw and motor drive system. This supply of heat can be further controlled by applying cooling or heating to the various barrel zones on the extruder by a series of air or water cooling systems. This is important since the amount of heat that is absorbed by the polymer needs to be closely monitored. The temperature of the extruder melted polymer is usually between 390°F and 450°F, and it is also under high pressure (2000 to 4000 psi).

Breaker Plate/Screen Pack

The molten polymer leaves the extruder in the form of two ribbons. It then goes through a screen pack which consists of one or more wire mesh screens, positioned against the breaker plate. The breaker plate is a perforated solid steel plate. Screen packs prevent foreign contaminants from entering the pipe wall and assist in the development of a pressure gradient along the screw. This helps to homogenize the polymer. To assist in the changing of dirty screen packs, many extruders are equipped with an automatic screen changer device. It removes the old pack while it inserts the new pack without removing the die head from the extruder.

Die Design

The pipe extrusion die supports and distributes the homogeneous polymer melt around a solid mandrel, which forms it into an annular shape for solid wall pipe⁽⁹⁾. The production of a profile wall pipe involves extruding the molten polymer through a die which has a certain shaped profile.

The die head is mounted directly behind and downstream of the screen changer unless the extruder splits and serves two offset dies.

There are two common types of die designs for solid wall pipe; the spider die design and the basket die design. They are illustrated in Figure 5. These designs refer to the manner in which the melt is broken and distributed into an annular shape and also the means by which the mandrel is supported.